A Clinical, Pathological and Demographic Study of an Unusual Locomotor Disorder of Sheep

by

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ABSTRACT

Kangaroo Gait is a locomotor disorder of sheep, which was first described in New Zealand in 1978, and was subsequently reported in the United Kingdom, initially in 1986. The reported features of the condition included acute onset bilateral forelimb paresis in adult female sheep occurring during lactation or late gestation, Wallerian degeneration of the radial nerves, subsequent regeneration, and, in most cases, clinical recovery. The aetiology of Kangaroo Gait remained obscure and there was little information regarding the incidence, the geographical distribution or the economic importance of this condition. This study was undertaken with the aims of characterising Kangaroo Gait in northern Britain in terms of its clinical, pathological and demographic features.

Thirteen adult female sheep from six flocks in south west Scotland, which had presented with an abnormal forelimb gait, were subjected to a clinical investigation, and four of these adult female sheep, as well as two lambs from one adult female, were submitted for pathological examination. The anamnesis for each flock did not reveal consistent problems with general management, nutrition, disease occurrence, or the presence of toxic plants or chemicals. Apart from the abnormal locomotion, physical examinations and ancillary investigations did not detect any consistent abnormalities. Neurological examinations resulted consistently in findings of bilateral forelimb paresis and reduced muscle bulk of the proximal forelimbs. Variable findings included proprioceptive deficits in the forelimbs and normal pedal withdrawal reflexes in all four limbs. A clinical diagnosis of Kangaroo Gait was determined for the 13 sheep. Evidence of Wallerian degeneration was found in the radial nerves of one adult female (onset of clinical signs during lactation), and minor changes were found in the radial nerves of a second (onset of clinical signs during gestation) but no significant abnormalities were detected in the peripheral nerves of the remaining adult females or the lambs. Non-specific changes were detected in the spinal cord of two adult females and the brain of one adult female (onset of clinical signs during gestation). Results suggested that Kangaroo Gait could occur in adult female sheep of a number of breeds, between the ages of one and seven years, onset of clinical signs could occur during late gestation or early to mid lactation, and recovery from clinical signs was not dependent on cessation of lactation. It was suggested that a range of pathological changes were associated with this condition, and that close observation of animals around the time of onset of clinical signs, and recruitment of individuals for detailed pathological examinations at that time, would be essential for determining the aetiopathogenesis of Kangaroo Gait.

In order to gain more information, two questionnaire studies were undertaken. The first survey was mailed to veterinary surgeons in all practices in Northern Britain which, according to the Directory of Veterinary Practices (Hall, 1997), provided veterinary care for sheep, and the second was mailed to sheep flock owners and managers located in the Scottish Borders, who were recruited via veterinary surgeons. Response rates of 84.7% and 30.7% were achieved. In total, 29.7% and 24.1% of respondents had identified one or more cases of Kangaroo Gait in their practice area or flocks at some time. Almost all respondents who had identified cases indicated that adult females were affected, most often during lactation, and less commonly during late gestation. Results suggested that Kangaroo Gait was more common among commercial cross breeds, and was less common on hill farms than upland or lowland farms. The annual number of affected individuals and flocks had increased since the condition was first identified. Comparing the results of the two surveys revealed that a majority of cases of Kangaroo Gait and other locomotor disorders were not reported to veterinary surgeons. Further epidemiological investigations could prove useful in determining risk factors for the occurrence of Kangaroo Gait. However, it was suggested that economic crises in the UK sheep industry, accompanied by a perception that Kangaroo Gait is of little economic importance, make it unlikely that detailed studies of this condition will be conducted in the foreseeable future.

In loving memory of

Laurie Adair Clements

(1917-1997)

and

Susan Newham

(1918-1996)

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DECLARATION

I, Archie Campbell Adair Clements, do hereby declare that the work carried out in this thesis is original, was carried out by myself or with due acknowledgement, and has not been presented for the award of a degree at any other University.

Archie C. A. Clements

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In conclusion, I would like to thank my parents, brothers and friends for making their love and support felt so strongly across the miles.

LIST OF ACRONYMS

AGIDT	Agar Gel Immuno-Diffusion Test
ALP	Alkaline Phosphatase
AST	Aspartate Aminotransferase
BDV	Border Disease Virus
BHB	Beta-Hydroxybutyrate
CEI	Comparative Epidemiology and Informatics
CK	Creatine Kinase
CCN	Cerebrocortical Necrosis
CNS	Central Nervous System
Dept. Vet. Path.	Department of Veterinary Pathology
DAFF	Department of Agriculture, Fisheries and Forestry
DRG	Dorsal Root Ganglia
DSVS	Demographic Study of Veterinary Surgeons of Northern Britain
EAE	Enzootic Abortion of Ewes
EDTA	Ethylenediamine Tetra-Acetic Acid
FAMP	Farm Animal Medicine and Production
GGT	Gamma-Glutamyltransferase
GLDH	Glutamate Dehydrogenase
GSH-PX	Glutathione Peroxidase
H&E	Haematoxylin and Eosin
IFP	Idiopathic Fore Limb Paresis
LMN	Lower Motor Neurone
MAFF	Ministry of Agriculture, Fisheries and Food
MV	Maedi-Visna
ODD	Ovine Digital Dermatitis
OJD	Ovine Johnes' Disease
PEM	Polioencephalomalacia
PNS	Peripheral Nervous System
SERAD	Scottish Executive Rural Affairs Department
UGVS	University of Glasgow Veterinary School
UK	United Kingdom
UMN	Upper Motor Neurone

CHAPTER 1

INTRODUCTION AND REVIEW OF THE LITERATURE

1.1. GENERAL INTRODUCTION

There are various methods used by the clinician to obtain, integrate and process information for the purpose of undertaking a clinical investigation. Such information is gained by determining an anamnesis, performing a clinical examination, making observations of the environment of the patient and undertaking appropriate ancillary investigations (Radostits and others, 1994). Tissues can be obtained from the live animal via biopsy. If an individual dies, or when a group of animals is affected by disease and an individual is available for sacrifice, a necropsy can be undertaken. Examination of materials obtained via biopsy and necropsy is the basis of pathological investigation of disease. The aims of pathological investigations are to determine the cause (aetiology), the mechanism of development (pathogenesis), and the morphological and functional alterations induced as a result of disease. Such aims are achieved by the use of a variety of molecular, microbiological, immunological and morphological techniques (Cotrin and others, 1994).

Epidemiology is the study of diseases, and the factors that determine the occurrence of diseases, as they affect populations (Thrusfield, 1995). Epidemiological investigations usually involve the application of hypotheses derived from observations made on a sample of the population. The aims of epidemiological investigations can be to determine the origin of a disease of known aetiology, to investigate diseases of unknown aetiology, to acquire information on the ecology and natural history of a disease, to plan and monitor disease control programmes, and to assess the economic effects of a disease. A necessary part of an epidemiological disease investigation is to count affected animals so that the amount of a disease is known, and to relate the number of affected animals to the size of the population at risk (Thrusfield, 1995). The act of measuring population size, distribution and composition is termed demography (Thrusfield, 1995).

1.2. LOCOMOTOR DISORDERS IN SHEEP

1.2.1. Introduction

The word 'locomotion' originates from the Latin verbs loco (to place) and motare (to keep moving) (Collins Latin Dictionary Plus Grammar, 1997). In this study the following definition of locomotion will be used: the ability (of an animal) to move from one place to another. A locomotor disorder will be defined as any derangement or abnormality of function that alters, limits or prevents an animal's ability to undertake locomotion (adapted from Blood and Studdert, 1988). Locomotion is achieved from a complex interaction between the neurological system and the muscles, bones, joints, ligaments and tendons. The components of this complex interaction will define the term 'locomotor system'. Owing to the complexity and diversity of the components of the locomotor system, locomotor disorders themselves are diverse in nature. The locomotor disorder investigated in detail by this study is an idiopathic bilateral forelimb paresis in sheep termed 'Kangaroo Gait'. The list of locomotor disorders considered in this review is a select one, and only includes those sharing broad clinical or pathological features with the disorder under investigation.

1.2.2. The Functional Anatomical Basis for Clinical Examination of The Ovine Locomotor System

1.2.2.1. The Peripheral Nervous System Component

The afferent pathways of the peripheral nervous system (PNS) involved in locomotion include neurones distributed by spinal nerves to the surface of the body and limbs, that are concerned with sensation of pressure, touch, vibration, temperature, pain and kinesthetic sensations relating to joint angulation and muscle tension (Dyce and others, 1996). Axons course from receptor organs through peripheral and spinal nerves to the dorsal root ganglia (DRG). Neuronal cell bodies are located within the DRG, and their axons continue proximally to enter the central nervous system (CNS) via the dorsal rootlets (Dyce and others, 1996). The efferent pathways include lower motor neurones (LMN) in all the spinal nerves that innervate the muscles of the appendicular skeleton,

the cell bodies of which are located laterally in the ventral grey column. Axons leave the spinal cord through the ventral roots, and travel through spinal and peripheral nerves, terminating in muscle fibres (deLahunta, 1983; Dyce and others, 1996).

The neuromuscular spindle is a stretch receptor that participates in the stretch reflex (deLahunta, 1983). The stretch reflex involves termination of an afferent (sensory) neurone directly onto an efferent (γ-motor) neurone in the ventral grey column of the spinal cord (Cormack, 1987b; Gartner and others, 1993). Examples of the stretch reflex include the following tendon jerk reflexes: The biceps reflex which tests the median nerve, the triceps reflex which tests the radial nerve, and the patellar reflex, which tests the femoral nerve. The reflex pathway of the limb withdrawal (or flexor) reflex involves an additional interneurone existing within the spinal cord segment, which receives a synapse from the afferent neurone, and which in turn influences an efferent neurone in the same or adjacent spinal segments (deLahunta, 1983).

1.2.2.1.1. The Radial Nerve

The radial nerve derives from the seventh and eighth cervical nerves and the first thoracic nerve (Ghoshal, 1975). From its origin in the brachial plexus, the radial nerve passes ventrally and caudally to follow the musculospiral groove. It detaches branches to the skin of the caudal lateral aspect of the arm and the triceps brachii, tensor fasciae antibrachii and anconeus muscles. The triceps brachii muscle is the major extensor of the elbow, although the long head also acts to flex the shoulder joint (Ghoshal, 1975). During its course in the musculospiral groove, the radial nerve divides into a superficial and a deep branch. The superficial branch innervates the dorsal aspects of the metacarpus, the medial accessory digit, the abaxial surface of the third digit and the axial (interdigital) side of the third and fourth digits. The deep branch innervates the extensor carpi radialis, extensor digitorum communis, abductor digiti I longus, extensor digitorum lateralis, and ulnaris lateralis muscles. The extensor carpi radialis muscle acts to extend and fix the carpal joint and to fix the elbow. The extensor digitorum communis and extensor digitorum lateralis muscles act to extend the carpal and digital joints and to flex the elbow joint and the abductor digiti I longus muscle acts to extend the carpal joint. Morphologically belonging to the extensor group, but functionally a

flexor of the carpal joint, muscle ulnaris lateralis also assists with extension of the elbow (Ghoshal, 1975). Damage to the radial nerve in the distal part of the arm results in paralysis of the carpal and digital extensors and sensory deficits, whereas damage to the proximal arm results in the above, plus paralysis of the elbow extensors (Vaughan, 1964; Dyce and others, 1996). The latter prevents fixation of the elbow, resulting in a 'dropped' elbow, and prohibits the limb from bearing weight (Vaughan, 1964; Dyce and others, 1996).

1.2.2.2. The Central Nervous System Component

The upper motor neurone (UMN) system is located in the CNS and is responsible for the regulation of posture and tone, and for the initiation of voluntary movement. Voluntary movement is controlled in part by a postural system, which recruits extensor reflexes in the proximal limbs for the supporting and propulsive phases of locomotion, and in part by a voluntary control system, which recruits flexor reflexes to initiate the protractive phase of locomotion (Latshaw, 1974). Anatomically, the voluntary control system is divided into the pyramidal and the extrapyramidal systems. The pyramidal system is mostly concerned with the performance of finely tuned movements, whereas the extrapyramidal system, which is the more important system in domestic animals (deLahunta, 1983), is concerned with the control of coarser movements, particularly of stereotyped locomotor movements (Dyce and others, 1996). The functions of the UMN system are performed by excitement or inhibition of lower motor neurones. The cerebellum mediates the UMN system via integration of information gained from pyramidal and extrapyramidal feedback, from the vestibular apparatus, and from proprioceptive pathways (Latshaw, 1974; deLahunta, 1983). Proprioceptive pathways include spinal cord segmental reflexes (with or without the involvement of interneurones), and projections to the cerebellum and sensory areas of the cerebral cortex. Proprioception can be tested by assessing various postural reflexes, including: proprioceptive positioning, placing reflexes, wheelbarrowing, extensor postural thrust, hemistanding and hemiwalking, and hopping reflexes (deLahunta, 1983; Oliver and others, 1997).

According to Hoffmeyr (1978), the sheep is a poor subject for neurological examination. In a neurological examination of 100 clinically normal adult sheep, the fore limb tendon jerk reflexes were only intermittently present, and the patellar reflex, although always present, varied tremendously in the degree of response. The extensor thrust reflex was clinically unreliable and the placing reflex was virtually absent when a sheep was held horizontally with the front legs brought into contact with a solid object. The placing reflex was present in all sheep where the forequarters were raised and lowered. The righting reflexes and hopping reflexes were also present in all sheep.

1.2.3. Pathology of the Ovine Locomotor System

1.2.3.1. The Neurone

Neurones are extremely diverse in their morphological and biochemical characteristics, and the effects of different toxins and metabolic disturbances can be highly selective and regionalised (Jubb and Huxtable, 1993). The nerve cell body contains a nucleus surrounded by cytoplasm (termed perikaryon) (Cormack, 1987a; Burkitt and others, 1993b; Storts, 1995). Usually the nucleus is centrally located (Cormack, 1987a; Burkitt and others, 1993b) and margination of the nucleus is a non-specific indication of degenerative change, especially when combined with a loss of staining affinity (Jubb and Huxtable, 1993). Chromatolysis is a term that describes clearing of the perikaryon due to dispersal of the rough endoplasmic reticulum (Nissl granules), and it is always indicative of a pathological lesion (Jubb and Huxtable, 1993). Central chromatolysis is often seen in lower motor neurones in response to axonal injury, especially when the injury occurs close to the cell body, and in this situation is termed the axon reaction (Storts, 1995). Central chromatolysis can also occur in upper motor neurone degenerations, where the affected cells often proceed to necrosis and dissolution. Neurones also respond to permanent loss of synaptic connections by becoming atrophied, which is characterised by a reduction in size of the perikaryon (Jubb and Huxtable, 1993). Other changes include liquefaction and vacuolation. Liquefaction may be a result of ischaemia, hypoxia, hypoglycaemia, thiamine deficiency-induced encephalopathies and some chemical toxicities, and may be misinterpreted as autolytic change (Jubb and Huxtable, 1993). Vacuolation is a feature of many viral infections,

metabolic and toxic conditions and lysosomal storage diseases (Koestner and Jones, 1997).

Myelinated axons are surrounded by a segmented myelin sheath, which has an insulatory function (Cormack, 1987a). The myelin sheath is interrupted at regularly spaced intervals termed nodes of Ranvier (Cormack, 1987a). Axonopathies that involve direct injury to the axon may be distal or proximal (Koestner and Jones, 1997). Distal axonopathies are more common and occur in a number of chronic toxicities (such as organophosphate poisoning) and genetically determined conditions. The largest and longest axons are usually affected, such as the proprioceptive and motor tracts of the spinal cord, the optic tract and the recurrent laryngeal nerve. Acute, focal injury to a myelinated axon results in changes termed Wallerian degeneration. Within 24 hours of focal mechanical injury, the portions of the axon distal, and several internodes proximal, to the transected area, begin to degenerate. Focal swellings occur, and fragmentation becomes evident after 48-72 hours (Jubb and Huxtable, 1993; Storts, 1995).

1.2.3.2. The Peripheral Nervous System

Peripheral nerves are composed of one or more bundles (fascicles) of nerve fibres (Burkitt and others, 1993b). In the PNS, all axons are enveloped by Schwann cells, which provide structural and metabolic support. Each axon, together with its investing Schwann cell, is surrounded by delicate vascular supporting tissue called endoneurium and each fascicle is surrounded by specialised, cellular support tissue called perineurium (Gunderson and Low, 1968). Schwann cells undertake myelination of axons, and each internode is myelinated by a single cell (Gartner and others, 1993; Burkitt and others, 1993b). Following Wallerian degeneration in the PNS, myelin sheaths are rapidly retracted by Schwann cells. Myelin degradation and removal is performed both by macrophages and Schwann cells (Stoll and others, 1989), which begin to proliferate, forming bands along the former course of the axon, termed Bungner's bands. If the cell body is uninjured there is potential for regeneration, however, if the cell body dies, Wallerian degeneration of the axon leads to dissolution of the neurone (Jubb and Huxtable, 1993; Storts, 1995). Providing conditions are favourable for regeneration, axonal sprouts from the original or adjacent neurones progress along Schwann cell

bands, leading to reformation of the nerve fibre (Jubb and Huxtable, 1993). Loosely textured, cell-sparse nodular structures, termed Renaut bodies, have been described in conjunction with evidence of repeated episodes of demyelination, particularly at sites of subclinical nerve entrapment (Neary and others, 1975; Jefferson and others, 1981; Duncan and others, 1987). Ortman and others (1983), were able to produce Renaut bodies experimentally, by compressing peripheral nerves, suggesting that these structures form as a response to repeated mechanical stress.

1.2.3.3. The Central Nervous System

The CNS is composed of neurones, neuroglia (astrocytes, oligodendrocytes, ependymal cells), microglia and mesenchymal cells that compose the blood capillaries (Cormack, 1987a; Burkitt and others, 1993b; Storts, 1993). Malacia is a term that describes the gross softening of nervous tissue resulting from necrosis of an area of neuroglia and contained neurones (Koestner and Jones, 1997).

Oligodendrocytes function to provide and maintain the myelin sheaths investing axons of the CNS, and have a supporting role for the metabolism of cell bodies (Cormack, 1987a; Burkitt and others, 1993b). One oligodendrocyte myelinates several axonal internodes, and death of an oligodendrocyte results in the demise of all myelin sheath segments supplied by that cell. Following damage to axons in the CNS, the initial changes of Wallerian degeneration are similar to that of the PNS, however the regenerative response is poor owing to the complex arrangement and limited regenerative ability of oligodendrocytes. The result is usually the permanent loss of axons, myelin and oligodendrocyte cell bodies (Jubb and Huxtable, 1993). Oligodendrocytes proliferate in unfavourable conditions, such as hypoxia or trauma (Manuelides and Manuelides, 1985), resulting in an increase in oligodendrocyte numbers adjacent the neurones, a phenomenon termed satellitosis (Koestner and Jones, 1997).

Astrocytes are the interstitial cells of the CNS, and they function to mediate metabolic exchange between neurones and the circulation, and to maintain a favourable intercellular environment for the survival and electrical activity of neurones (Burkitt and

others, 1993b). Severe injury to astrocytes results in swelling of the cytoplasm, followed by disintegration (Jubb and Huxtable, 1993; Storts, 1995). When astrocytes or cells around them are damaged, the cytoplasm may swell and becomes eosinophilic, and some cells may acquire additional nuclei. Reactive astrocytes of this type are called gemistocytes (Jubb and Huxtable, 1993; Storts, 1995). Proliferation of astrocytes and their processes is called astrogliosis, a phenomenon that accompanies Wallerian degeneration, neuronal loss, sustained CNS oedema, and many viral encephalitides. Astrocytes may also phagocytose cellular debris, particularly myelin (Jubb and Huxtable, 1993).

The microglia form a tissue reserve of potential phagocytes (Cormack, 1987a; Burkitt and others, 1993b). They occur most frequently in the grey matter in the vicinity of neurones, and in both the grey and white matter adjacent blood vessels (Cormack, 1987a; Burkitt and others, 1993b; Storts 1995). They become hypertrophic in response to tissue damage, and may proliferate (Jubb and Huxtable, 1993). They may also transform to become macrophages, and phagocytose myelin debris, gaining a foamy cytoplasm and a pyknotic nucleus, at which point they are termed gitter cells (Jubb and Huxtable, 1993).

In diffuse inflammatory or neoplastic conditions, a perivascular space surrounding capillaries and venules, called the Virchow-Robin space, accumulates reactive and invading cells, a phenomenon termed perivascular cuffing (Jubb and Huxtable, 1993).

1.2.3.4. The Skeletal Muscles

Muscle fibres are elongated, multinucleate, contractile cells (Burkitt and others, 1993a). Groups of muscle fibres supplied by branches of a single motor neurone are termed motor units (Cormack, 1987b; Burkitt and others 1993b). The synapse of a motor neurone at a muscle fibre is termed a motor end plate. At this point the axon swells to form the terminal bouton, which contains mitochondria and membrane-bound synaptic vesicles encasing the neurotransmitter acetylcholine (Burkitt and others, 1993b).

Disruption of the motor nerve fibre deprives muscle fibres of their normal low-level tonic stimulus, and prevents their contraction against resistance. The result is paralysis and atrophy of the denervated muscle fibres (Hulland, 1993). Reduction in muscle fibre diameter is rapid in peripheral denervations (Hulland, 1993). Within 2-3 weeks, two-thirds of muscle mass will be lost, although this deficit is often difficult to determine without the assistance of mean fibre diameter measurement by morphometry (Hulland, 1993).

During the first few weeks following denervation the diameter of muscle fibres becomes monophasic and progressively narrower (Hulland, 1993). After about two weeks there is an apparent increase in the concentration and prominence of muscle nuclei (Hulland, 1993; McGavin, 1995). In muscles where severance of the contributing motor neurones has been incomplete, grouping of muscle fibres that have retained neural connections (large fibres) between those that have not (atrophic fibres), becomes apparent (Hulland, 1993). Atrophic fibres may become angular in cross section due to pressure from adjacent normal fibres (Hulland, 1993; McGavin 1995). Re-innervation may be via sprouting from either the original or adjacent nerve fibres (Hulland, 1993).

1.2.4. Kangaroo Gait

A condition termed Kangaroo Gait was first described in New Zealand in 1978 by Moffat, as a locomotor disorder of lactating ewes, characterised by difficulty in placing the front feet, knuckling of the fetlock joints of the fore limb, and compensatory placement of the hind feet under the body. Affected ewes progressed with shortened steps if unhurried, and with a bounding action if pressed. Cumulative incidence was low (less than 1% per annum). Onset of clinical signs occurred 2-3 weeks after lambing. Ewes recovered when the lambs were weaned, with the more severe cases taking up to one month post-weaning to recover. A similar gait abnormality of lactating ewes (Duffel and others, 1986; Barlow and Greig, 1986; Down, 1986) and pregnant ewes (Clarkson, 1991) has been reported in the United Kingdom (UK).

Moffat (1978) found ketonaemia in four of nine clinical cases sampled. A negative energy balance due to heavy lactation was suggested as the cause. Eleven control

animals from the same flock were not ketonaemic. Five clinical cases and 4 control sheep were also hyperphosphataemic. Plasma calcium, magnesium and urea concentrations were normal for all clinical cases and controls. Duffell and others (1986) found serum concentrations of calcium, magnesium, inorganic phosphorus, selenium, copper and plasma creatinine kinase to be within normal ranges for two clinical cases in lactating ewes.

The neurological signs of the two clinical cases of Kangaroo Gait described by Duffell and others (1986) were consistent with bilateral radial nerve paresis, based on the absence of tactile placing and diminished pedal withdrawal reflexes in the fore limbs. Tissues from these two cases were subjected to a pathological examination, six weeks after the onset of clinical signs. Light microscopy of the radial nerves revealed Wallerian degeneration in a high proportion of nerve fibres. No changes were evident in the CNS. Severe myopathy of the mm. triceps brachii and extensor carpi radialis was evident, with depletion of intramuscular nerve fibres. Sarcocystosis, causing a mild non-suppurative myositis, was also apparent in many muscles including the heart.

The results of a more detailed pathological examination of these two cases were published by O'Toole and others (1989). Sections of the radial and tibial nerves from these cases were compared to those of a control ewe. Nerve fibre loss was evident in the radial nerves of both affected animals, in addition to clusters of thinly myelinated, regenerating axons. Numerous Renaut bodies were also evident. Electron microscopy revealed that axonal degeneration was restricted to myelinated axons, and provided evidence that fibre degeneration was long-standing, based on the presence of Bunger's bands composed of Schwann cells containing little myelin debris (myelin degradation takes several weeks). Small non-myelinated axonal sprouts were present, indicating regeneration, although the presence of early stages of axonal degeneration suggested concurrent fibre loss. Teased fibre preparations also provided evidence of axonal degeneration, and decreased nerve fibre density was demonstrated in the radial nerves by morphometry. Owing to the presence of Renaut bodies, the authors suggested an aetiology of acute bilateral nerve compression.

The clinical and pathological findings in six cases of Kangaroo Gait, reported by Barlow and Greig (1986) differed from those reported by Duffell and others (1986) and O'Toole and others (1989). Signs of a forelimb paresis were similar to those of previous reports, however two ewes presented with additional ataxia of the hindlimbs. Light microscopic studies demonstrated spongy change in the neuropil at several locations within the brain and spinal cord, ventral root ganglionopathy and neuronal degeneration of the hippocampus and cervical spinal cord. Wallerian degeneration was evident in the radial nerves of 3/6 cases, accompanied by myopathy of the m. triceps brachii. Skeletal and cardiac muscle from 3/6 cases also had heavy infestations with sarcosporidia. An attempt was made to explain the variability of the neurological and pathological findings by suggesting that radial nerve degeneration could have been a later consequence of spongy change within the CNS. A suggestion was made that tissue deficiencies of B-Vitamins, known causes of spongy change within the CNS and ganglionopathy, may have been implicated in the aetiology of Kangaroo Gait. It seems likely that a number of disease entities, including Kangaroo Gait, were present in these cases. This possibility was duly acknowledged.

The three pregnant ewes described by Clarkson (1991) demonstrated onset of clinical signs at least 7 weeks pre-partum. Other characteristics of the condition, including a low flock incidence (0.025%) and clinical signs of an acute onset of forelimb paresis and a leaping hind limb gait, were similar to those described by earlier reports in cases among lactating ewes. Blood biochemical parameters were within normal ranges for the three affected ewes. Two cases improved and lambed normally, the third case died of pneumonia and was examined pathologically. Although the specific techniques used for pathological examination and the precise nature of pathological changes in the brachial nerves were not described, the pathological findings were considered typical (for Kangaroo Gait).

The aetiology of Kangaroo Gait remains obscure. There is little information regarding the incidence, the geographical distribution or the economic importance of this condition. There are few detailed pathological descriptions of Kangaroo Gait, and the results of clinical investigations have been contradictory. The consistent findings are of an acute onset bilateral forelimb paresis in adult female sheep occurring during

lactation, or possibly pregnancy, characterised pathologically by Wallerian degeneration of the radial nerves and subsequent regeneration leading, in most cases, to a clinical recovery.

1.2.5. Other Peripheral Neuropathies and Neuromuscular Disorders of Sheep

Specific peripheral neuropathies affectting the locomotor system are rarely reported in sheep. An idiopathic congenital hypomyelination of the peripheral nerves was reported in a lamb by Braund and others (1993). The clinical presentation included intermittent tremors and ataxia. Pathological findings were of amyelination (or hypomyelination) of axons with no evidence of nerve fibre loss, necrosis or phagocytosis. The pathological lesions occurred in all nerves examined, which included the radial, median, ulnar, sciatic and tibial nerves.

Botulism is caused by a neurotoxin produced by the bacterium *Clostridium botulinum*. The toxic agent acts on the nerve terminals where it blocks release of acetylcholine. Sudden death is a common clinical finding, however affected animals may be seen exhibiting tremors, inhibited respiration, bloat, listlessness, a stiff gait, paresis, and paralysis, rapidly progressing to death (Lught and others, 1995; Lught and others, 1996).

1.2.6. Peripheral Neuropathies and Neuromuscular Disorders of Other Ungulate Species

Damage to the radial nerve is usually due to trauma, and may accompany fracture of the humerus or first rib, or avulsion of the nerve roots when the leg is forcefully abducted (Rooney, 1963; Bacher and Potkay, 1976). The radial nerve is the most commonly affected nerve in post-operative neuropathy of the horse, and is difficult to distinguish from post-operative myopathy of the triceps muscle (Taylor, 1992). In one report by Lopez and others (1997), fracture of the cervical and thoracic vertebrae in the horse presented with neurological signs identical to radial nerve paralysis.

Suprascapular nerve injury is caused by traumatic compression of the nerve against the cranial edge of the scapula, or stretching of the nerve when the limb is thrust backwards

(Dutton and others, 1999). The major clinical signs are atrophy of the infraspinatus and supraspinatus muscles, and an abnormal gait resulting from instability of the shoulder joint (Schneider and Bramlage, 1990). Subclinical suprascapular nerve entrapment has been reported in the horse, with pathological changes indicative of repeated demyelination and remyelination (Duncan and others, 1987). Similar changes, including the presence of Renaut bodies and distal axonopathy, were evident in an idiopathic condition of horses in Japan, characterised clinically by knuckling of all four limbs and muscle atrophy (Furuoka and others, 1998). Cauvin and others (1993) diagnosed axillary nerve paralysis and non-specific brachial plexus neuropathy in two horses using electromyography.

The femoral nerve has been commonly reported as being damaged in calves during difficult parturition, leading to atrophy of the quadriceps femoris muscle and signs of femoral nerve paralysis (Tryphonas and others, 1974; Healy, 1997). Femoral nerve paralysis has also been reported in horses following anaesthesia (Dyson and others, 1988). Damage to the obturator nerve has been implicated in calving paralysis in cows, however experimental unilateral sectioning of the obturator nerve did not result in an inability of the animal to stand. This led to the suggestion that additional damage to the sciatic nerve roots, joints, ligaments, tendons and muscles contributes to the manifestation of this condition (Cox and others, 1975). Damage to the sciatic nerve, in combination with muscular damage, has been demonstrated to be the cause of 'downer cows', where pressure on one pelvic limb occurs during prolonged recumbency (Cox and others, 1982). Iatrogenic damage to the sciatic nerve has been reported in pigs following intramuscular injection (Alstine and Dietrich, 1988).

A peripheral neuropathy, affecting the vagus and sciatic nerves, and nerves of the brachial plexus has been reported in cattle (Hill and others, 1996), characterised clinically by dysphagia, bloat and a weak, shuffling gait, and pathologically by thickening of the myelin sheaths. A genetic basis was suggested for this condition.
Phytotoxicities causing changes in the peripheral nerves have been reported, including: *Karwinskia humboldtiana* (Coyotillo) poisoning of goats in the United States (Charlton and Pierce, 1970; Charlton and others, 1971), characterised clinically by a stiff, hypermetric gait and tremors, and pathologically by segmental demyelination and

Wallerian degeneration in a range of peripheral nerves; *Ipomoea carnea* poisoning of goats in India (Tirkey and others, 1987), characterised clinically by ataxia and hindlimb paralysis, and pathologically by focal Wallerian degeneration of the sciatic nerve and vacuolation of spinal cord grey matter; and *Melochia pyramidata* toxicity of cattle in El Salvador, characterised clinically by hindlimb paralysis and pathologically by Wallerian degeneration of the sciatic nerve (Palmer and Woodham, 1975).

Grass sickness and 'Mal Seco' are idiopathic dysautonomias of the horse with similar pathological changes in the peripheral autonomic nervous system, including chromatolysis of the neurones of the autonomic ganglia and loss of neurones in the submucosal plexus of affected gut (Pogson and others, 1992; Uzal and others, 1992; Doxey and others, 1995). Stringhalt and Australian stringhalt are similar but distinct conditions of the horse with imprecisely defined aetiologies. Clinical signs are often sudden in onset, and variable. The characteristic sign is exaggerated flexion of one or both hocks, either intermittently, or with every stride (Cahill and others, 1985; Araya and others, 1998). Results of histopathological studies have differed and no definite causative lesion in the central or peripheral nervous systems or musculature has been identified, leading to speculation of a functional neuromuscular aetiology (Cahill and others, 1985). Laryngeal hemiplegia is a condition of the horse, characterised pathologically by distal axonopathy of the left recurrent laryngeal nerve, and occasionally the right (Cahill and Goulden 1986a-d). Evidence of changes in the lateral cuneate nuclei, including axonal spheroids, has been reported, suggesting a central nervous component to the aetiology of this condition (Cahill and Goulden, 1989).

1.2.7. Other Causes of Abnormal Locomotion in Adult Sheep

1.2.7.1 Disorders of the Central Nervous System

Polioencephalomalacia (PEM) (synonym; cerebrocortical necrosis, CCN) affects sheep of all ages (Gabbedy and Richards, 1977). The clinical signs include: aimless wandering, ataxia, blindness, recumbency, hyperaesthesia, spasms of the extensor muscles, opisthotonus and death (Terleki and Markson, 1961; Edwin and Jackman, 1982; Stebbings, 1982). Grossly, the brain may appear oedematous, with disseminated

areas of yellowish discolouration throughout the cerebral cortex. The major histopathological change is laminar or focal necrosis of the cerebral cortex (Terleki and Markson, 1961). PEM has been associated with thiamine deficiency, induced by thiaminase (Piersen and Jensen, 1975; Edwin and Jackman, 1982), and high sulphur intake (Rousseaux and others, 1991; McAllister and others, 1992; Olkowski, 1992; Blowey and Packington, 1994; Bulgin and others, 1996; Low and others, 1996).

Viral encephalitides and encephalomyelitides in adult sheep in the UK include louping ill, visna and Aujesky's disease (Henderson and others, 1995). Louping ill virus is transmitted by the sheep tick *Ixodes ricinus.* Clinical signs in affected sheep vary from a transient ataxia to rapid onset coma and death. Commonly, sheep exhibit hyperexitability, fine muscle tremors, incoordination, paralysis and convulsions. Pathological findings include a bilateral, non-suppurative encephalitis, most severe in the hindbrain (Reid, 1991). Visna is one manifestation of infection with the maedi-visna virus. Clinical signs occur in sheep greater than 2 years of age and include progressive weight loss, ataxia and paresis of the hindlimbs, eventually leading to hindlimb paraplegia. The clinical course may last up to one year (Dawson, 1980). Pathological changes include focal demyelination of the spinal cord, periventricular inflammation and small necrotic foci in the brain (Georgsson and others, 1982; Watt and others, 1990).

Scrapie is a transmissible spongiform encephalopathy of sheep caused by an infectious agent, believed to be a prion. Disease onset is dependent both on the presence of the infectious agent, and a susceptible host genotype. Clinical signs include weight loss, intense pruritus, hyperaesthesia, hindlimb ataxia, muscle tremors, bruxism and aggression (Petrie and others, 1989; Linnabary and others, 1991; Clark and Moar, 1992). The major pathological changes associated with Scrapie are widespread vacuolation of the neurones and neuropil of the medulla and midbrain (Linnabary and others, 1991).

The bacterium *Listeria monocytogenes* is a common cause of meningoencephalitis in sheep of all ages. Listerial myelitis has also been reported (Seaman and others, 1990). The neurological signs of listerial meningoencephalitis include: depression, circling, head tilt, trigeminal and facial nerve paralysis, and recumbency with paddling

movements of the limbs (Scott, 1993). Pathological changes include microabscessation, focal gliosis and perivascular cuffing, usually affecting the brainstem, and trigeminal neuritis (Charlton and Garcia, 1977; Krueger and others, 1995). Outbreaks of disease are often associated with feeding poor quality silage (Groenstoel, 1979; Low and Renton, 1985; Wiedmann and others, 1994; Wiedmann and others, 1997). Thrombotic meningoencephalitis caused by *Haemophilus agni* (*Histophilus ovis*) has also been reported (Philbey and others, 1991; Cassidy and others, 1997). Bacterial meningoencephalitis, and abscessation of the spinal cord and vertebral bodies are common disorders in young lambs following septicaemic episodes, but are rarely reported in adult sheep (Scott and others, 1991; Scott and others, 1994). A mixture of bacteria, dominated by α-haemolytic Streptococci, was isolated from one case of post-septicaemia focal meningitis in an adult ram, showing signs of cerebellar dysfunction (Scott and others, 1993a).

The two major parasitic diseases of the central nervous system of sheep in the UK, reported to cause locomotor abnormalities, are coenurosis and sarcocystosis. Coenurosis (synonyms: gid, sturdy) is caused by the presence of *Coenurus cerebralis*, the metacestode of the larval stage of *Taenia multiceps*, in the brain of affected animals. Clinical signs are referable to the location of the cyst, and may include skull softening, circling, head pressing, head aversion, unilateral blindness, unilateral paresis, postural deficits, and cerebellar signs (Skerrit and Stallbaumer, 1984; Tirgari and others, 1987). Encephalitis and encephalomyelitis due to *Sarcocystis tenella* and other non-specific sporozoons have been reported. Clinical signs include ataxia, fore- or hind- limb paresis, and flaccid paralysis. Pathological findings include non-suppurative encephalitis, myelitis, meningitis, and myositis, accompanied by the presence of protozoon cysts in the affected tissues (Morgan and others, 1984; O'Toole and others, 1986; O'Toole and others, 1993; Scott and others, 1993b; Henderson and others, 1997; Sargison and others, 2000).

Paspalum staggers occurs in sheep grazing grasses of the genus *Paspalum*, which contain the fungus *Claviceps paspali* in the seed head. Ingestion of the fungus results in tremors, hyperexcitability and ataxia. Animals grazing plants, or ingesting soils, containing a number of species from the genus *Penicillium* may also show tremors, as

well as spastic ataxia and convulsions. In both cases the aetiological agents are tremorgenic mycotoxins (Cysewski, 1973; Menna and Mantle, 1976; Mantle and others, 1978). Tremors, ataxia and convulsions are also signs of phalaris staggers, a disorder that arises from ingestion of grasses of the genus *Phalaris*. The aetiological agent is a tryptamine alkaloid. The main pathological changes include pigmentation in the midbrain, medulla, spinal cord and dorsal nerve root ganglia, and degenerative changes in the spinal cord (East and Higgins, 1988; Lean and others, 1989; Halderen and others, 1990). Ryegrass staggers is a less fatal disorder resulting in spasms, stiffness and tetany (de Lahunta, 1983). The aetiological agent is unknown, although Gallagher and others (1977) provided evidence that fungal tremorgens ingested with grass, or from soil, may have a causative role in this condition.

Tetanus is caused by neurotoxins produced by the bacterium *Clostridium tetani*. Spores of *C. tetani* gain entry via wounds arising from shearing, docking, or castration, or iatrogenically via injection sites. The neurotoxin is elaborated by the vegetative form of the bacterium and travels to the spinal cord, via the peripheral nerves, where it blocks release of inhibitory neurotransmitter. Clinical signs include severe stiffness of gait, muscular rigidity, tremors, hyperaesthesia, recumbency, inhibited respiration and death (de Lahunta, 1983; Char and others, 1993; Aslani and others, 1998).

Treatment of sheep with the organophosphate anthelminthic haloxon has resulted in intoxication characterised clinically by hindlimb ataxia, progressing to hindlimb paralysis, and pathologically by bilateral demyelination of the cervical and thoracic spinal cord (Williams and others, 1976).

1.2.7.2. Metabolic Disorders

Various metabolic disturbances may cause abnormalities in locomotion as a component of their presenting signs. Hypocalcaemia and ketosis (synonym: pregnancy toxaemia) tend to occur in late gestation in ewes, the former is characterised clinically either by flaccid paralysis, or by muscle twitching, tetany, ataxia and recumbency (Oetzel, 1988) and the latter by apparent blindness, depression, star-gazing, head tilt, nystagmus, circling, recumbency and convulsions (Jopp and Quinlivan, 1981; Marteniuk and Herdt,

1988; Singh and others, 1992; Scott and Woodman, 1993). Hypomagnesaemia usually presents as sudden death in post-parturient ewes at pasture, however, in the early stages, affected animals may be observed staggering, proceeding to recumbency, with paddling movements of the legs and muscle twitching (West and Bruere, 1981).

1.2.7.3. Painful Disorders

Pain receptors, termed nociceptors, are located at the terminus of small unmyelinated or poorly myelinated axons, which extend from cell bodies located in the spinal ganglia. Axons continue into the spinal cord grey matter where they may terminate on interneurones, which synapse on lower motor neurones to complete a local reflex arc, the basis of the limb withdrawal reflex. Conscious perception of pain involves synaptic connections between the afferent neurone and neuronal cell bodies or dendrites of the multisynaptic spinothalamic tract. The spinothalamic tract terminates in the thalamus, from which axons project to the cerebral cortex (de Lahunta, 1983).

Behavioural changes associated with pain of the legs or feet include alterations of gait or stance, and recumbency. These responses often represent an attempt to minimise pain and in many cases may accelerate healing (Sanford and others, 1986).

Foot rot and ovine digital dermatitis (ODD) are the most common cause of lameness in UK sheep flocks, with footrot accounting for 40% and ODD accounting for 44% in a study reported by Grogono-Thomas and others (1998). Foot rot is an infectious dermatitis originating in the interdigital epidermis and extending to the epidermal matrix of the hoof, ultimately resulting in separation of the horn (Egerton and others, 1969). Transmission of the bacterium *Dichelobacter nodosus* between sheep is necessary for spread of the disease, but maceration or laceration of the interdigital tissue and invasion by the ubiquitous organism *Fusobacterium necrophorum* are essential for colonisation by *D. nodosus* (Egerton and others, 1969). An additional factor is the presence of *Arcanobacterium pyogenes*, which may assist in the colonisation of the interdigital epidermis by *F. necrophorum* (Roberts and Egerton, 1969). Spirochaetes have been implicated in the aetiology of a severe, virulent form of ovine footrot in which *D . nodosus* is absent (Naylor and others, 1998). In the absence of *D. nodosus*, invasion by

F. necrophorum results in the development of ODD, characterised by varying degrees of necrosis of the interdigital epithelium (Parsonson and others, 1967). Extension of ovine interdigital dermatitis infection into the digital cushion and distal interphalangeal joint results in a painful condition termed foot abscess (Roberts and others, 1968; West, 1983a). *A. pyogenes* is thought to contribute to the pathological progression of this condition (Roberts and others, 1968) which appears to have a higher attack rate in rams than ewes (West, 1983a; West, 1983b). Unlike footrot, ODD and foot abscess are not contagious conditions.

Additional infectious diseases of the foot and skin of the leg which may cause lameness in adult sheep include; dermatophilosis (strawberry footrot), orf virus infection, ulcerative dermatosis and contagious ecthyma (Boundy, 1983). Interdigital fibromas, white line disease, acute and chronic laminitis, foreign body penetration, and iatrogenic granulomas are disorders of the tissues of the foot that also commonly result in lameness (Morrow and others, 1973; Boundy, 1983).

Lameness and stiffness of gait accompanied by joint effusion, recumbency and a reduced range of joint movement are characteristics of arthritis. Infectious arthritis may arise from direct trauma, by extension of infection from adjacent tissue, iatrogenically, or via haematogenous spread of a systemic infection. Maedi Visna Virus and Ovine Progressive Pneumonia Virus infections have been known to cause arthritis in adult sheep (Cutlip and others, 1985; Angus, 1991).

Osteochondrosis is a painful condition of the joints thought to arise from intensive feeding of rapidly growing animals. (Scott and others, 1996; Doherty and others, 1996). Exostoses of the joints and resulting lameness have been reported due to molybdenum toxicity (Pitt and others, 1980) and fluorosis (Botha and others, 1993).

Bone fractures, joint luxations, and ligament, tendon or muscle ruptures, result in extreme alterations in gait, both due to the mechanical defect and resulting from attempted avoidance of pain caused by movement of the affected limb (Morin and others, 1989; Semevolos and others, 1998). Myopathies in sheep include nutritional myopathy due to selenium/ vitamin E deficiency or lupinosis, but cases in adult sheep

are unusual (Gabbedy and others, 1977; Allen and others, 1992). Exertional rhabdomyolosis has been reported in sheep, with presenting signs of recumbency and haematuria (Peet and others, 1980).

1.3. VETERINARY DATA COLLECTION

1.3.1. Census and Sample Surveys: General Principles

A census is a count of all individuals in a population. Censuses are the only means of exactly measuring the distribution of a variable in a population, however they are often prohibitively expensive or impossible to conduct (Thrusfield, 1995). Estimates of the distribution of a variable can be made to a desired degree of accuracy by obtaining data from a representative sample of the population (Levy and Lemeshow, 1991). The size of the sample selected depends on the size of the population, the expected prevalence of the variable(s), the desired accuracy of the estimate and the desired confidence in the estimate (Levy and Lemeshow, 1991). Selection of a representative sample may be achieved by simple random sampling, where study units are randomly selected from the whole population, or by employing varying levels of stratification on known variables in the population to ensure that representation is obtained from all groups (strata) within the population (Thrusfield, 1995). Samples are usually obtained from lists of individuals in a population, termed 'sampling frames'. A representative sample can only be dependably drawn if all members of a population are included (enumerated) in the sampling frame. Completely enumerated lists are rarely found, either because they are out of date, because individuals are able to prevent themselves from being included, or because certain members of the population do not possess the attribute(s) necessary for inclusion (Dillman, 1978).

1.3.2. Questionnaire Surveys

Questionnaires are the main instrument for data collection in censuses and are widely used in epidemiological studies (Vaillancourt and others, 1991; Bourque and Fielder, 1995). Questionnaires have been used in the UK for the collection of data relating to a wide range of veterinary topics, as disparate as the use of diagnostic tools in veterinary

practice (Douglas and Eckersall, 1985), the demographic characteristics of animal populations subject to veterinary care (Mellor and others, 1999) and risk factors for disease (Wood and others, 1998). Subjects have included veterinary students (Scott and others, 1995), veterinary surgeons in practice (Taylor, 1984; Gunn, 1993), and animal owners or managers (Gettinby and others, 1987; French and others, 1992; Menzies and others, 1994; Chambers and others, 1995; Coles, 1997; Grogono-Thomas and others, 1998; Cetinkaya and others 1998; Smith and others, 1998; Hoinville and others, 1999; Milnes and Green, 1999; Pearce, 1999).

1.3.2.1. Sources of Error and Measures of Questionnaire Quality

A major source of error in estimates of the characteristics of populations obtained by questionnaire surveys is non-response. A relatively small number of non-responses provides the potential for the introduction of considerable error into calculations of the results of questionnaire surveys (Dillman, 1978). Considerable effort is made in designing and implementing questionnaire surveys in order to minimise non-responses. Reliability, best measured as the repeatability of responses after a brief time period, and validity, which compares questionnaire responses with independent measures of the same variable, are important indicators of questionnaire quality (Vaillancourt and others, 1991). Measures of questionnaire reliability and validity are often not undertaken or reported (Vaillancourt and others, 1991). Table 1.1 summarises the use of quality indicators and related implementation practices in published mail questionnaire-based studies, relating to diseases of sheep, cattle and pigs, undertaken in the UK. The table is not exhaustive and only includes publications where methods of questionnaire design and implementation were at least partly described. Response rates varied significantly (2.5-78.3%). Where two or more follow-ups were implemented, the range of response rates was 52.8-78.3%; where there was a single follow-up response rates were 45.2 and 73.5%, and where there were no follow-ups response rates were 2.5 and 19.9%. Where pretesting was described, response rates were 52.8-78.3%, and where no pretesting was described, response rates were 2.5-73.5%. These results support the suggestion that a greater investment of resources in the planning, implementation and follow-up of veterinary-related questionnaire surveys results in higher response rates, and therefore reduces the potential effects of non-response bias.

There were few attempts to assess the reliability and validity of the questionnaire responses.

Table 1.1 Quality indicators of UK mail questionnaire studies of diseases in farm animal species.

Disease	Subject	Pretesting	Follow-Ups	Response Rate (%)	Reliability + Validity	Publication
Swine Dysentery	Veterinary Surgeons	Not Described	Not Performed	10/400 (2.5)	Not Reported	Taylor (1984)
Congenital Chondrodystrophy	Veterinary Surgeons	Not Described	Two Follow-Ups	108/152 (71.1)	Not Reported	Gunn (1993)
Blowfly Strike	Sheep Farmers	Tested on 10 Farmers	Two Follow-Ups	1 819/2 451 (74.2)	Both Tested	French and others (1992)
Tail Biting	Pig Farmers	Not Described	Single Postcard	47/104 (45.2)	Not Reported	Chambers and Others (1995)
Lameness	Sheep Farmers	Not Described	Not Performed	647/3 250 (19.9)	Not Reported	Grogono-Thomas and Others (1998)
Johne's Disease	Dairy Farmers	Tested on 11 Farmers	Three Follow-Ups	2 953/3 772 (78.3)	Reliability Tested	Cetinkaya and others (1998)
Proliferative Enteropathy	Pig Farmers	Tested on 6 Farmers	Two Follow-Ups	319/569 (56.1)	Not Reported	Smith and others (1998)
Scrapie	Sheep Farmers	Tested on 20 + 300 Farmers	Two Follow-Ups	7 090/11 554 (61.4)	Not Reported	Hoinville and others (1999)
Lice	Dairy Farmers	Tested on 3 Farmers	Two Follow-Ups	1 040/1 970 (52.8)	Validity Tested	Milnes and Green (1999)
Enteric Diseases	Pig Farmers	Not Described	Single Letter	175/238 (73.5)	Not Reported	Pearce (1999)

1.3.2.3. Types of Questionnaires

There are three basic types of questionnaire study, defined by the method by which they are administered. These are personal interviews, telephone interviews and mail surveys (Dillman, 1978). Self-administered questionnaires are those which are completed by the subjects of the survey. Unsupervised self-administered questionnaires are usually mailed to the subjects of the study whereas supervised self-administered questionnaires

involve the presence of the surveyor or supervising personnel (Bourque and Fielder, 1995). Selection of the most appropriate method depends on the specific requirements of the study and involves consideration of a wide variety of factors. For example, if cost is the main limiting factor, mail surveys may be the best option, whereas if the major requirement is for rapid speed of administration, telephone interviews are preferable. Response rates tend to be lower for mail surveys than for personal and telephone interviews, even if focussed on target populations, or if questionnaires are accompanied by premailings, follow-ups, or various incentives (Dillman, 1978; Bourque and Fielder, 1995).

1.3.2.4. Design of Self-Administered Questionnaires

Responses are thought to be higher if questionnaires are presented in a booklet format with front and back covers reserved for contents aimed at stimulating interest rather than obtaining information from the respondent (Dillman, 1978). The ordering of questions is a subject on which opinions vary. Dillman (1978), and Bourque and Fielder (1995), argued that questions should be grouped by topic, with questions requesting demographic information placed last, but stated that some prefer to order questions from the easiest to the most difficult, with demographic questions placed first. Vertical continuity of questions and response categories is also considered important (Dillman, 1978).

With respect to designing the questions themselves, attention should be focused on both the structure of the question and the choice of words. Question structure may be open-ended, close-ended or partially close-ended. An open-ended question structure allows for respondents to express themselves freely, and is commonly used where a precise piece of information is required from a large number of possible answers (Dillman, 1978). Although it is generally recommended to limit the use of open-ended questions in self-administered mail surveys, they are particularly useful for recording of continuous variables (Vaillancourt and others, 1991; Bourque and Fielder, 1995). Coding of responses for purposes of data analysis can be difficult for open-ended questions (Vaillancourt and others, 1991). A close-ended structure provides a list of choices that may be ordered, usually a gradation of a single dimension or scale, or

unordered, where choices are discrete categories. Close-ended questions are easier to code and are generally used where the responses of the subjects can be anticipated. A compromise is the partially close-ended question, which provides a list of choices with an option affording the freedom to include additional information (Vaillancourt and others, 1991). Specific wording of questions is aimed at avoiding bias, hypothetical and objectionable questions, vagueness, and unnecessary complexity (Dillman, 1978).

Pretesting is an essential practice in developing a successful questionnaire. A number of different groups should be pretested. These include trained professionals (colleagues) who understand the objectives of the study, people who are likely to use the results generated by the study, and people who represent a cross-section of potential respondents, but who, if possible, are not included in the survey population themselves (Dillman, 1978). The purpose of pretesting is to evaluate the questionnaire in terms of the design, the degree of understanding of each question, and the information provided by the responses (Vaillancourt and others, 1991).

1.3.2.5. Implementation

The inclusion of a cover letter is essential for successful questionnaire surveys. The letter should contain explanations of the purpose of the study, how the respondent was selected and reasons as to why the respondent should reply (Bourque and Fielder, 1995), as well as a guarantee of confidentiality (Dillman, 1978). The inclusion of an addressed return envelope with the questionnaire has been shown to increase response rates, with the highest response rates achieved using a return envelope with a commemorative stamp affixed (Choi and others, 1990). Details such as the choice of stationery and the method by which the questionnaire package is assembled are considered to affect the response rate (Dillman, 1978).

It has been shown that the use of up to eight follow-ups has increased response rates significantly (Siemiatycki and others, 1979). Dillman (1978) recommends the use of a postcard reminder one week after the initial mail-out, followed by replacement questionnaires and accompanying letters at three and seven weeks.

1.4. SUMMARY

Investigations of disease can be focused on affected individuals, molecules, cells and tissues of affected individuals, or on groups or populations of individuals. Attention to the varying levels of interaction between disease agents and affected animals forms the basis of clinical, pathological and epidemiological investigations. There are few descriptions of the clinical, pathological or epidemiological characteristics of the condition known as Kangaroo Gait. The aims of this thesis, therefore, are:

1) To describe the findings of detailed clinical examinations of a number of sheep affected with the locomotor disorder known as Kangaroo Gait.

2) To describe the pathological changes associated with Kangaroo Gait.

3) To obtain information on the size, distribution, genders, age groups, breeds and environs (demographic characteristics) of the populations consisting of those sheep affected with, and those sheep at risk, of Kangaroo Gait.

CHAPTER 2

CLINICAL INVESTIGATIONS OF KANGAROO GAIT

2.1. INTRODUCTION

There are few published reports of the condition known as Kangaroo Gait, which was first described in New Zealand in 1978 by Moffat, as a locomotor disorder of lactating ewes. The presenting signs included difficulty in placing the front feet, knuckling of the fetlock joints of the fore limb, and compensatory placement of the hind feet under the body. Affected ewes progressed with shortened steps if unhurried, and with a bounding action if pressed. Period prevalence was low (less than 1% per annum). Onset of clinical signs occurred 2-3 weeks after lambing and ewes recovered when the lambs were weaned, the more severe cases taking up to one month post-weaning to recover. Four of nine clinical cases were ketonaemic and a negative energy balance due to heavy lactation was suggested as the cause. Eleven control animals from the same flock were not ketonaemic. Five clinical cases and 4 control sheep were also hyperphosphataemic. Plasma calcium, magnesium and urea concentrations were normal for all animals tested.

Reports of a similar gait abnormality of lactating ewes (Duffel and others, 1986; Barlow and Greig, 1986; Down, 1986) and pregnant ewes (Clarkson, 1991) have been published in the UK. The neurological signs of the two clinical cases of Kangaroo Gait described by Duffell and others (1986) were consistent with bilateral radial nerve paresis, based on the absence of tactile placing and diminished pedal withdrawal reflexes in the fore limbs. The clinical findings in six cases of Kangaroo Gait, reported by Barlow and Greig (1986) differed from those reported by Duffell and others (1986). Signs of a forelimb paresis were similar to those of previous reports, however two ewes presented with additional ataxia of the hind limbs. The three pregnant ewes described by Clarkson (1991) demonstrated onset of clinical signs at least 7 weeks pre-partum. Other characteristics of the condition, including a low flock incidence (0.025%) and clinical signs of an acute onset of forelimb paresis and a leaping hind limb gait, were identical to those described by earlier reports in cases among lactating ewes. Two cases improved and lambed normally and the third case died of pneumonia. The occurrence of this condition in non-lactating ewes challenged suggestions made in previous reports that Kangaroo Gait was associated with lactation (Moffat, 1978; Barlow and Greig, 1986; Down, 1986), although this point was not discussed in the aforementioned report by Clarkson (1991). Blood biochemical parameters were within normal ranges for affected

ewes in the reports by Duffell and others (1986) and Clarkson (1991).

In March and April 1999, three Texel gimmers from a farm in South Lanarkshire that presented with gait abnormalities of varying severity, were examined by the author at the University of Glasgow Veterinary School (UGVS). All three gimmers were pregnant and due to lamb in the four week period commencing 20 April 1999. A search of the literature located the aforementioned reports of Kangaroo Gait, describing similar clinical signs and neurological findings to those observed in the three gimmers. Owing to the paucity of published information pertaining to the clinical syndrome known as Kangaroo Gait, it was decided to undertake a detailed clinical study of this condition.

2.2. MATERIALS AND METHODS

2.2.1. Recruitment of Clinical Cases

The three Texel gimmers from the South Lanarkshire flock (Flock 1) presenting with gait abnormalities described above were referred to the Division of Farm Animal Medicine and Production (FAMP) at UGVS, with the aim of establishing a diagnosis through clinical examinations and appropriate ancillary investigations. Upon determining a clinical assessment of bilateral forelimb paresis in the three gimmers, case records at UGVS were examined for the previous five years. One previous case of bilateral forelimb paresis was identified in a lactating Scottish Mule gimmer from a second farm in South Lanarkshire (Flock 2), presenting to UGVS in April 1998.

Conversation with the owners of both flocks with referred clinical cases revealed that additional adult female sheep had been affected with the same clinical signs as those referred to the Division of FAMP, and another ewe was affected in a flock neighbouring Flock 2 (Flock 3). Arrangements were made to visit the three affected flocks. Clinical examination of a Texel ewe and a Texel gimmer from Flock 1, a Texel cross gimmer from Flock 2, and a Suffolk cross ewe from Flock 3 revealed findings of bilateral forelimb extensor paresis. All four adult females were lactating at the time of examination, however onset of clinical signs had been during late gestation in the two sheep from flock 1, and during early lactation in the sheep from flocks 2 and 3.

In June 2000, visits were requested from UGVS to two flocks in Ayrshire (Flocks 4 and 5) with sheep demonstrating an abnormal forelimb gait. Three Scottish Mule ewes from Flock 4 and a Lleyn X Rouge de l'Ouest ewe hogg from Flock 5 were examined. All four sheep demonstrated bilateral forelimb paresis, all were lactating at the time of onset of clinical signs, and all were (or had been) nursing lambs. In June 2000 a further case of a gait abnormality, similar to that of the three Texel gimmers from Flock 1, in a three-quarter Texel cross Scottish Mule ewe from a flock located in Ayrshire (Flock 6), was reported to UGVS. This ewe was transported to UGVS for further investigation. A clinical examination revealed neurological changes consistent with a bilateral forelimb paresis. She too had been lactating at the time of onset of clinical signs, and was nursing lambs.

A total of 12 adult female sheep with neurological findings of bilateral forelimb paresis were examined and an additional case with similar abnormalities was located in the case files at UGVS. These 13 adult female sheep came from six flocks in South Lanarkshire and Ayrshire, in the south west of Scotland. Cases from five of the flocks were examined following referral to UGVS by first opinion veterinary surgeons, and the case from the sixth was examined following personal communication between the author and the flock owner. Five of the six flocks were visited in person by the author and the case from Flock 6 was examined on the premises of UGVS. Table 2.1. summarises the characteristics of the cases recruited for this study.

2.2.2. Obtaining a History

A detailed flock history was recorded for each of the six flocks from which cases of Kangaroo Gait were examined. The flock history was recorded on a history sheet that contained a list of questions (Appendix 1). In four cases (Flocks 1, 2, 3 and 6) the history taking was performed by interviewing the owner or manager of the flock during the visit (or in the case of flock 6, at UGVS), at which time the history sheet was completed by the author. In two cases (flocks 4 and 5) the history taking was performed by mailing the history sheet to the flock owners who then completed the history sheets and returned them to the author by post. Completion of the history sheet by interview took approximately 30 minutes.

Table 2.1. Summary of cases recruited for the clinical study of Kangaroo Gait.

Flock 1.	**Case A:**	Texel gimmer	Examined 23/03/1999
	Case B:	Texel gimmer	Examined 23/03/1999
	Case C:	Texel gimmer	Examined 10/04/1999
	Case D:	Texel gimmer	Examined 28/05/1999
	Case E:	Texel ewe	Examined 28/05/1999
Flock 2.	**Case F:**	Scottish Mule gimmer	Examined 27/04/1998
	Case G:	3/4 Texel cross gimmer	Examined 28/05/1999
Flock 3.	**Case H:**	Suffolk cross ewe	Examined 28/05/1999
Flock 4.	**Case I:**	Scottish Mule gimmer	Examined 04/06/2000
	Case J:	Scottish Mule ewe	Examined 04/06/2000
	Case K:	Scottish Mule ewe	Examined 04/06/2000
Flock 5.	**Case L:**	Lleyn cross Rouge ewe hogg	Examined 04/06/2000
Flock 6.	**Case M:**	3/4 Texel cross ewe	Examined 09/06/2000

Question one sought basic information regarding location, size, area grazed, age structure and breeds of sheep in the flock, as well as the presence of other livestock species. Question two sought specific information regarding the year of diagnosis, presence of cases recognised by the flock owner but not diagnosed by a veterinarian, age, breed, outcome, physiological state, parity and survival of offspring of sheep affected with bilateral forelimb paresis in the flock. Question three sought information on the date of commencement and length of the lambing period, the average body condition score of ewes and tups at tupping, and any changes to these parameters in the previous ten years. Question four requested dates between which sheep had been housed. Question five sought information on disease accreditation, occurrence of metabolic and neurological disorders, occurrence of abortions, the presence of any other

major health problems in the flock and use of organophosphates. Questions six, seven and eight sought information on grazing management, supplementary feeding, known soil deficiencies, use of fertilisers, herbicides and pesticides, and the presence of poisonous plants or in-fill sites or local industries on or near the farm.

2.2.3. General Physical Examination

A general physical examination was performed on all 13 cases of Kangaroo Gait recruited for this study. The results of the clinical examination were recorded on a tick sheet identical to that used by the Division of FAMP to record clinical findings in farm animal referral and teaching cases (Appendix 2). The breed, gender, age, and body condition score (grade 0.0-5.0) were recorded. A subjective examination was performed which described abnormalities in the demeanour, posture, gait, size, body condition and fleece quality, and any other visibly obvious abnormalities. The rectal temperature was obtained. Examination of the cardiovascular system included auscultation of the heart, and examination of the ocular, oral and vaginal mucus membranes. Examination of the respiratory system included auscultation of the thorax, and examination of the nares and rhinarium. The heart rate and respiratory rate were recorded. Examination of the alimentary system included auscultation of the rumen, palpation of the abdomen, examination of the mouth, and examination of the faeces. The skin, lymph nodes, mammary glands and vulva were examined. Examination of the musculoskeletal system included palpation of the muscles, bones and joints, and examination of the feet, including the interdigital spaces. Examination of the eyes was performed using both a pen torch, and an ophthalmoscope.

2.2.4. Neurological Examination

A neurological examination was performed on each of the 13 cases of Kangaroo Gait recruited for this study. The neurological examination followed a similar format to that of the University of Glasgow Veterinary Hospital Neurological Examination Sheet (Appendix 3), but only in two cases was this sheet used to record the findings of the neurological examination. In the remaining eleven cases, the abnormal findings of the

neurological examination were summarised in the margin of the general physical examination tick sheet (Appendix 2).

The gait was observed and described. Hopping on individual limbs, as well as hemi-stand and hemi-walk tests and wheelbarrow tests were performed. Proprioception was tested by flexing the metacarpo- and metatarso- phalyngeal joints, so that the dorsum of the foot bore the weight of the animal, and observation was made of the ability of the animal to replace it's foot in the correct weight bearing position. The patellar stretch reflex, and the extensor carpi radialis stretch reflex were tested using a neurological hammer (or equivalent). Muscle tone was tested by passive manipulation of the limbs and assessing the degree of resistance, and the muscles were palpated to assess muscle bulk. Pain perception and the flexor withdrawal reflex were assessed by pinching the interdigital skin, and observing the animals' reaction. Observations were also made regarding cranial nerve function.

2.2.5. Ancillary Investigations

Blood was obtained from each of the clinical cases except case G. Samples were collected in separate glass tubes containing Lithium Heparin, Calcium EDTA, and no anticoagulant (clotted sample). Serum was collected from the clotted sample and frozen at -20°C.

Routine haematology, including red and white cell counts, a white cell differential, and a smear analysis, was performed using the calcium EDTA sample at the UGVS in-house laboratory. Blood biochemistry was performed using part of the lithium heparin-containing sample, also at the GUVS in-house laboratory. Biochemical analyses included measurements of electrolyte, urea, creatinine, total bilirubin, alkaline phosphatase (ALP), aspartate aminotransferase (AST), γ-glutamyltransferase (GGT), glutamate dehydrogenase (GLDH), creatine kinase (CK), total protein, albumin, globulin and β-hydroxybutyrate (BHB) concentrations.

Trace-element and vitamin analyses were performed at the Scottish Agricultural Colleges Veterinary Science Division laboratories. Glutathione peroxidase (GSH-PX)

concentrations were determined from lithium heparinised blood samples. Copper, vitamin B-12 and vitamin E concentrations were determined from lithium heparinised blood or thawed serum samples. Maedi-visna Agar Gel Immuno- Diffusion Tests (AGIDT) were also performed at the Scottish Agricultural Colleges Veterinary Science Division laboratories, using thawed serum samples. Border Disease Virus (BDV) antibody and antigen detection was performed at the Moredun Research Institute, Penicuik, using lithium heparinised blood or thawed serum samples. A list of names and addresses of laboratories to which samples were sent in this study is provided in Appendix 4.

2.3. RESULTS

2.3.1. Flock Histories

2.3.1.1. Common Factors

No sheep were known to have repeat episodes of bilateral forelimb paresis in following years. All adult female sheep demonstrating signs of bilateral forelimb paresis gave birth normally, to live twin lambs (unless otherwise mentioned). Other than six lambs that were euthanased at UGVS (section 3.2.1.) from flock 1, all other lambs born to cases of bilateral forelimb paresis survived to weaning. None of the flocks were accredited under any of the major disease accreditation schemes. No poisonous plants were identified in the swards of any of the six farms, nor were there any infill sites or local industries located near any of the farms.

Aspects of the histories that differed between flocks are summarised below.

2.3.1.2. Flock 1.

Two hundred hectares were dedicated to sheep production. The farm also comprised a beef suckler enterprise and a pedigree herd of Blonde D'Aquitaine cattle. There were approximately 650 adult female sheep (150 gimmers and 500 ewes), ten adult tups, 150 ewe hoggs and 1100 young lambs. Three hundred adult female sheep belonged to the

Texel breed, 200 were Scottish Blackface and 150 were Texel cross Scottish Blackface. The first case of bilateral forelimb paresis from this flock affected a 3-year-old Texel ewe, which was examined by a veterinary surgeon in March 1998. In 1999 there were four cases in Texel gimmers, and one case in a 4-year-old Texel ewe. All cases had been examined by a veterinary surgeon. Four sheep were moved off the farm before their clinical outcome was known and two sheep recovered while still nursing lambs. Initial onset was during late gestation in all six sheep. Lambing occurred outdoors and commenced on 20 April, lasting approximately six weeks. The average body condition of the ewes was reported to be good at tupping, but poor at lambing, particularly those affected with the gait abnormality. There were 30 abortions in the 1999 lambing season. No diagnosis was reached, although chlamydial abortion had been previously diagnosed in this flock. Ovine Johnes' Disease (OJD) and scrapie were considered important disease problems, with eleven cases of scrapie diagnosed in the previous two years. All ewes were permanently grazed on improved pasture (mostly containing rye grass) and ewe hoggs were grazed on unimproved hill pasture. Ewes received big bale silage from the end of January to the end of lambing, and pellets containing 18% protein during the last 4-6 weeks of pregnancy, as well as molasses tub licks for two months before lambing (only provided in 1998 and 1999). Silage was home-cut, and contained ryegrass, timothy and clover. The quality of silage was poor in 1998 and 1999, owing to wet weather and inadequate wilting. The farm soil was known to be deficient in cobalt and copper. Ewes always received an injectable vitamin E/selenium supplement before tupping and lambing. All sheep were dipped with an organophosphate-containing dip in October. Fertilisers containing 20:10:10 nitrogen, phosphorus and potassium were spread in spring and late summer. Spot-spray herbicides were used, not on pastures grazed by sheep, but possibly on pastures incorporated into home-cut silage.

2.3.1.3. Flock 2.

Eighty hectares were dedicated to sheep production, and the farm also comprised a dairy cattle herd. There were 170 adult female sheep (60 gimmers and 110 ewes), four adult tups and 240 young lambs. Adult female sheep included 126 Scottish Mules and 44 three-quarter Texel crosses. The first case of bilateral forelimb paresis that was examined by a veterinary surgeon occurred in April 1992, although one case occurred in

April 1991 that did not receive veterinary attention. There was one case per year from 1991-1995, then two cases in 1997, and one case each in 1998 and 1999. All cases were in gimmers - seven Scottish Mules, and one three-quarter Texel cross. Seven cases recovered while still nursing lambs, and one case was sent to UGVS where it was euthanased. Initial onset was during early lactation in all cases. All affected gimmers were nursing twin lambs. Lambing commenced 8 February in 1999 and lasted approximately seven weeks. The lambing date had been bought forward by three weeks compared to previous years. The average body condition of the ewes was reported to be good at tupping, but poor at lambing. Ewes were housed at night between 8 February and 31 March in 1999 and allowed out during the day, although most ewes stayed indoors. Chlamydial abortion and pregnancy toxaemia were considered important disease problems in this flock, but neither disease occurred in 1999. All sheep grazed permanent improved pasture containing rye grass, timothy, clover and cocksfoot. Ewes normally received supplementation with proprietary brand 18% protein 'ewe rolls', but not in 1999. Ewes received home-cut hay containing grass and clover, molasses and vitamin block supplements, but no silage. There were no known soil deficiencies. Fertiliser, containing 21:8:11 nitrogen, phosphorus and potassium, was spread on pastures in April. Sheep were dipped with organophosphate containing dips in September or October each year. No herbicides or pesticides were used on the sward.

2.3.1.4. Flock 3.

Twelve hectares were dedicated to sheep production, and sheep grazed alongside cattle, goats and horses. There were five gimmers, 25 ewes, ten previous year's lambs, and 40 young lambs. Adult females included 21 Texel crosses, seven Suffolk crosses, two Lleyns and one Scottish Blackface. There has only been one case of bilateral forelimb paresis on this farm, which was examined by a veterinary surgeon in May 1999. This animal was a 7 year old Suffolk cross ewe, initially affected during lactation while nursing two foster lambs, having given birth to dead triplets. She recovered while still nursing the lambs. Two days prior to developing acute signs of bilateral forelimb paresis this ewe had spent three or four days on the premises of Flock 2. Lambing was at grass and commenced 8 April in 1999, lasting approximately three weeks. Ewes were in fair to average body condition at tupping and in somewhat poorer average body

condition at lambing. Sheep were shut in at night during the winter and spent the day time out at grass. There were no disease problems considered to be important in this flock. Sheep were rotationally grazed on improved pastures containing rye grass, timothy and white clover. Ewes were supplemented with molasses, and proprietary brand 18% protein 'ewe rolls', commencing eight weeks before lambing. Ewes were also supplemented with good quality purchased grass hay and some locally purchased big bale silage, fed from November to mid-May, and magnesium-containing composite block licks, provided at grass during the spring and summer. There were no known soil deficiencies. Fertilisers containing 20:10:10 nitrogen, phosphorus and potassium were spread on pastures in April. A broadleaf herbicide spot-spray was used on the sward. Dips were not used in 1999.

2.3.1.5. Flock 4.

Sixty-two hectares were devoted to sheep production. The flock consisted of 369 adult female sheep (75 gimmers and 294 ewes), 83 ewe hoggs, ten adult tups, and 640 young lambs. There were 282 Scottish Mule, 90 Texel and 80 Scottish Blackface adult female sheep in the flock. Three cases of bilateral forelimb paresis were first examined by a veterinary surgeon in June 2000, although one case occurred in June 1999 that did not receive veterinary attention. All cases occurred in Scottish Mules, including one gimmer, two three year old ewes and one five year old ewe. The gimmer that developed the gait abnormality in 1999 recovered while nursing lambs. Onset of clinical signs was during lactation in all four sheep, while nursing twin lambs. Lambing commenced 25 March 2000, and lasted for six weeks. Sheep were housed between February and April. The major disease problems in this flock included abortion (diagnoses of toxoplasmosis and chlamydial abortion were obtained), psoroptic mange (sheep scab) and foot rot. No organophosphate dips were used on the farm. Sheep were grazed on permanent pasture. Supplementary feeding at grass included 18% protein proprietary sheep blend, molasses liquid feed and magnesium supplementation. During housing, sheep received grass hay, 18% protein proprietary sheep blend and molasses liquid feed. There were no known soil deficiencies. Fertiliser containing 20:10:10 nitrogen, phosphorus and potassium were spread on the pasture. Herbicide was used on the sward.

2.3.1.6. Flock 5.

Seventy-five hectares were dedicated to sheep production. The flock consisted of 286 adult breeding female sheep (136 gimmers and 150 adult ewes), five tups, 39 shearling rams and 350 young lambs. Among adult female sheep, there were 100 Lleyns, 60 Rouge de l'Ouest, 12 Scottish Blackface and 10 Blue Texels. The first case of bilateral forelimb paresis was examined by a veterinary surgeon in May 1999. Two further cases, also examined by a veterinary surgeon, occurred in 2000. The farm owner recalled specific details of two of the sheep affected by the gait abnormality. One case was in a four year old Lleyn cross ewe, and the other was in a one year old Lleyn cross Rouge de l'Ouest ewe hogg. All sheep were initially affected with the condition during lactation and all recovered. Lambing commenced on 18 January and lasted until April. The average body condition of ewes at tupping and lambing was reported to be good. Sheep were housed between December and April. The flock was accredited under a maedi-visna accreditation scheme. There were ten cases of hypocalcaemia in 2000. Otherwise there were no major disease problems. While housed, sheep received hay and baled haylage, as well as beet pulp and a proprietary concentrate mix, containing 18-20% protein and added minerals, during the last six weeks of gestation. Haylage was home-cut and comprised grass and clover species. The quality of the haylage was poorer in 2000 when compared to previous years. Sheep were grazed on permanent pasture and did not receive dietary supplements at grass, except a general-purpose proprietary mineral supplement. No organophosphate dips were used on the farm. There were no known soil deficiencies. Fertiliser containing nitrogen, phosphate and potassium was spread on pastures in April. Broadleaf herbicides were used on the farm.

2.3.1.7. Flock 6.

Thirty-two hectares were dedicated to sheep production, and the farm also comprised 30 beef suckler cows. There were approximately 50 gimmers, 200 adult female breeding ewes, five adult tups, 400 young lambs, 50 ewe hoggs and 14 tup hoggs. Adult breeding females included 150 Texel cross Scottish Mules, 60 Texels, 20 Scottish Mules and 15 Suffolks and Suffolk crosses. There have been two cases of bilateral forelimb paresis in this flock, neither receiving attention from the first opinion veterinary surgeon. One

case occurred in 1999 in a four year old Texel cross Scottish Mule ewe, and the second case occurred in 2000 in a five year old three-quarter Texel cross Scottish Mule ewe (examined by the author). Both ewes were lactating and nursing twin lambs at the time of onset. The ewe affected in 1999 recovered around the time of weaning. Lambing commenced 20 April 2000 and lasted approximately four weeks. Lambing commenced ten days earlier in 1999. On average, ewes were reported to be in good body condition at tupping and lambing. Ewes were not housed in 2000, but were housed between mid-March and the end of lambing in 1999, at which time housed ewes had access to pasture during the day. There were no known health problems of major importance in the flock. Ewes were rotationally grazed on improved pasture containing rye grass and clover. Following lambing, no feed supplements other than proprietary molasses feed blocks containing magnesium were given in 2000, but in 1999 ewes received a home-mixed concentrate ration containing barley, soya and a standard proprietary mineral supplement. Good quality home-cut big bale silage was fed to pregnant ewes from January to May. There were no known soil deficiencies, and fertiliser containing 25:5:5 nitrogen, phosphorus and potassium was spread in early spring, as well as cattle manure, slurry and mixed sheep and cattle dung. Herbicides were used in restricted areas of the farm, and were not applied to parts of the sward used for making silage. Organophosphate dips were used in July 1999.

2.3.2. General Physical Examination

Table 2.2. summarises the findings of a general physical examination for each of the 13 cases of bilateral forelimb paresis. The time between onset of clinical signs and the general physical examination varied between sheep. Cases C, H and K were examined two weeks after, cases A, B, G, I and J were examined three weeks after, cases D, E, F and M were examined five weeks after and case L was examined six weeks after the onset of clinical signs. Subjectively, all animals demonstrated an abnormal gait of varying severity. The most mildly affected animals (cases B, D and G) appeared normal while standing, however, while walking, they demonstrated hypermetria of the forelimbs, and a bounding gait with knuckling of the forelimbs when pressed to move rapidly. Moderately affected animals (cases C, E, F, I, J, K, L and M) tended to prefer recumbency, and supported their body weight on the dorsal surface of the metacarpi

when grazing. They demonstrated difficulty in locomotion, and progressed with short hypermetric steps of the forelimbs, with the hind limbs positioned underneath the body, to support a greater proportion of the body weight. When pressed to move rapidly, the forelimbs would knuckle and the sheep would collapse into sternal recumbency. The worst affected sheep (cases A and H) were unable to support their body weight with the forelimbs for sustained periods of time, and were unable to propel themselves forward more than a few steps before knuckling of the forelimbs and recumbency would occur. The results of detailed neurological examinations of these 13 sheep are described in section 2.3.3.

No other abnormalities were detected on general physical examination, with the following exceptions: Cases A, B, F and H were in poor body condition (score 1.5 in a 0.0-5.0 scale). Cases I, J, K and L were tachypnoeic (respiratory rate >30 breaths/minute), which was considered to be a response to the stress of capture and handling. Case F was also tachypnoeic, and auscultation of the lungs revealed harsh respiratory sounds, indicating an abnormality of the respiratory system. Case H was slightly dull on subjective examination, and had excessive dental wear, which was probably contributing to her poor body condition. Case K had a mild chronic mastitis in both glands, and obvious teat lesions that were probably a result of orf virus infection. Cases B, C and M had breaks in the wool, and subsequent wool loss, probably as a result of stress, and case J had extensive wool loss which was believed by the owner to be a result of resolved psoroptic mange. Cases A and B had foot rot in all four feet, and case G had a severe toe abscess in one of the fore feet.

Table 2.2. Summary of the findings of the general physical examination of thirteen cases of Kangaroo Gait

CASE	BCS*	Subjective	Gestation/ Lactation**	Cardiovascular + respiratory	Alimentary	Repro-ductive	Musculo-skeletal	Integument
A	1.5	BAR+	Gestation	NAD++	NAD	NAD	↓ m. bulk‡	Foot rot
B	1.5	BAR	Gestation	NAD	NAD	NAD	↓ m. bulk	Foot rot Wool break
C	2.0	BAR	Gestation	Hyperpnoea	NAD	NAD	↓ m. bulk	Wool break
D	2.5	BAR	Gestation	NAD	NAD	NAD	NAD	NAD
E	2.0	BAR	Gestation	NAD	NAD	NAD	NAD	NAD
F	1.5	BAR	Lactation	tachypnoea harsh lungs	NAD	NAD	NAD	NAD
G	3.0	BAR	Lactation	NAD	NAD	NAD	↓ m. bulk	Toe abscess
H	1.5	Dull	Lactation	NAD	Dental wear	NAD	↓ m. bulk	NAD
I	2.0	BAR	Lactation	tachypnoea	NAD	NAD	↓ m. bulk	NAD
J	2.5	BAR	Lactation	tachypnoea	NAD	NAD	↓ m. bulk	Wool loss
K	2.5	BAR	Lactation	tachypnoea	NAD	Mastitis		Teat lesions
L	2.5	BAR	Lactation	tachypnoea	NAD	NAD	↓ m. bulk	NAD
M	2.5	BAR	Lactation	NAD	NAD	NAD	↓ m. bulk	Wool break

* BCS = Body Condition Score (scale 0.0 - 5.0).

** Refers to physiological state at time of onset of clinical signs.

+ BAR = Bright, Alert and Responsive.

++ NAD = No Abnormalities Detected.

‡ ↓ m. bulk = Reduced muscle bulk of the proximal forelimbs.

2.3.3. Neurological Examination

All thirteen sheep were subjected to a neurological examination. The abnormal findings of eleven cases were recorded in summary form only, and all neurological findings were recorded for the remaining two cases (B and C). Subjective assessments of the gait abnormalities, as described in section 2.3.2., and objective assessments of the hopping, wheelbarrow and hemistand/hemiwalk tests, resulted in findings of bilateral forelimb paresis in each of the thirteen cases, which was characterised by a restriction or a lack of ability of the forelimbs to support the body weight. Proprioceptive deficits of the forelimbs were evident in cases A, C and F, characterised by a delay in repositioning of the foot following manual flexion of the metacarpophalyngeal joints. Such deficits were

absent in case B and were not recorded in other cases. There were neither signs of weakness, nor proprioceptive deficits in the hind limbs of any of the cases examined. Patellar tendon jerk reflexes were normal in all cases, except case F, in which there was apparent patellar stretch hyperreflexia. Extensor carpi radialis stretch reflexes were difficult to assess, however there was evidence of areflexia in case B. Pedal withdrawal reflexes were normal in both fore- and hind- limbs of cases B and C (no abnormalities were recorded in the other cases), and a behavioural response was elicited by pinching the interdigital skin of all four limbs, suggesting pain perception was intact. All cases except D, E and F had palpable reduction of muscle bulk of the proximal forelimbs. Muscle tone was found to be difficult to assess, although was apparently normal in case B (no abnormalities were recorded in the other cases). No abnormalities of the cranial nerves were detected in any of the thirteen cases.

2.3.4. Ancillary Investigations

Tables of all haematology and biochemistry results from twelve cases of Kangaroo Gait are provided in Appendix 5. Case M had a mild leukocytosis due to neutrophilia, case C had a neutrophilia, but no overall increase in numbers of leukocytes and case K had a neutrophil left shift, although this was not accompanied by an increase in numbers of mature neutrophils or total leukocytes. Cases C (first sampling), E, H, J, K, and M had a reversed neutrophil: lymphocyte ratio, which was accompanied by lymphopaenia in cases E and H. Additionally, the neutrophil: lymphocyte ratio approached 1:1 in cases A, B, D, and I, which was accompanied by lymphopaenia and leucocytopaenia in case D. A mild reduction in erythrocyte numbers was evident in cases A and C (both samplings), which was manifest by a slightly decreased haematocrit in both animals (second sampling only, case C). Cases E and J were mildly thrombocytopaenic, and case C had slightly increased numbers of platelets on the second sampling.

Cases D, H, I, J, and K had mildly increased concentrations of urea, and creatinine concentrations were mildly increased in cases A, B, C (first sampling) and L. There were no significant alterations in concentrations of sodium, potassium, chloride, magnesium, or phosphate. Calcium concentrations were mildly decreased in cases B, C (both samplings), H, I, and M, and were mildly increased in case D. Total bilirubin

concentrations were normal in all 12 cases. Serum ALP concentrations were mildly increased in cases I, J and M, and were moderately increased in cases B and L (> two-fold increase). Concentrations of AST were mildly increased in cases A, E, F, I, J and K, and moderately increased in case M (> two-fold increase). Total protein concentrations were mildly increased in case L, and moderately increased in case E. Albumin concentrations were mildly decreased in cases C (both samplings) and H, and mildly increased in cases E, F, K and L. Globulin concentrations were mildly increased in cases A, E, J, L and M. Gamma-glutamyltransferase concentrations were mildly increased in cases K, L and M, and GLDH concentrations were mildly increased in case I, and moderately increased in cases J, K and M (six-ten fold increase). Beta-hydroxybutyrate concentrations were mildly increased in cases F, I, J, K and M, and moderately increased in case A. Creatine kinase concentrations were mildly increased in cases D, J, K, and L, and markedly increased in case M (fifteen-fold increase).

Table 2.3. summarises the results of trace element and vitamin concentrations in the serum of 11 cases. No testing was performed on cases A and G. Serum copper concentrations were normal except in case B (markedly decreased), case D (mildly decreased) and case E (mildly increased). Glutathione peroxidase concentrations were moderately decreased in case E, and increased in cases B, I, J and K. Serum vitamin E concentrations were increased in cases B, D, I and M. All serum vitamin B-12 concentrations were greater than 1000 ng/l, and were therefore considered normal.

Cases A, B, C, D, E, F, H, I, J, K, L and M were all negative for maedi-visna by AGIDT, suggesting that none of the cases sampled had been exposed to the maedi-visna virus. No antibodies to BDV, nor BDV antigens were detected in blood or serum samples submitted from cases A, B, C, D, H, I, J, K, L and M, suggesting that none of these cases had been exposed to BDV. Cases E and F were negative for BDV antibody, but insufficient sample volumes were submitted in these cases for BDV antigen detection.

Table 2.3. Summary of serum trace element and vitamin concentrations for twelve cases of Kangaroo Gait.

Case	Serum Copper (μmol/l)	Glutathione Peroxidase (u/ml)	Serum Vitamin E (μmol/l)	Serum Vitamin B-12 (ng/l)
B	**<1.0**	-	**7.1**	>1000
C	-	-	2.2	>1000
D	**6**	171	**6.4**	>1000
E	**39**	**38**	2.8	-
F	18	94	2.4	>1000
H	11	156	4.3	>1000
I	9	**325**	**7.0**	>1000
J	13	**253**	3.9	>1000
K	11	**256**	5.7	>1000
L	10	178	5.3	>1000
M	13	161	**8.6**	>1000
Reference Range	9 - 20	42 – 200	1.0 - 6.0	400 – 1000

Note. Figures in bold lie outside laboratory reference ranges.

2.4. Discussion

The presence of bilateral forelimb paresis was confirmed by clinical examination in all thirteen cases recruited for this study. As there is no other known condition of sheep with sole presenting signs of bilateral forelimb paresis, and as the anamnesis of these cases is consistent with those reported in the literature, it is concluded that all thirteen sheep were suffering from the clinical syndrome known as Kangaroo Gait. Therefore the results of this study indicate that Kangaroo Gait occurs in female sheep of all ages from one to seven years. It was also shown that onset of clinical signs could occur during late gestation as well as lactation. Additionally, it was evident that the condition occurred in the Texel breed, as well as various cross breeds, including the Scottish Mule (originating from a cross between the Scottish Blackface and the Blueface Leicester), Texel cross Scottish Mule, Suffolk cross and Lleyn cross Rouge de l'Ouest.

The results of this study suggested that weaning of the lambs was not essential to allow recovery of affected sheep, although from these data it was not possible to refute or support any suggestion that weaning may hasten the speed of recovery. It was evident that affected ewes were able to lactate normally and raise healthy lambs. No animals affected with Kangaroo Gait were known to suffer from subsequent episodes of the condition. It was not possible, however, to prove that repeat episodes do not occur, due to the small number of animals examined in this study, and the difficulties of identifying and recording cases of Kangaroo Gait for following up in later years.

Some cases described in the historical accounts given by the six flock owners were not examined by veterinary surgeons. It seems likely that these were indeed cases of Kangaroo Gait, owing to the striking and unique presenting signs of this condition, and the similarity to other cases in the same flocks that had been subjected to a veterinary examination. However, the possibility that the gait abnormalities observed in these sheep were due to other conditions, such as painful lesions of the foot, must be considered.

No historical evidence was provided to link Kangaroo Gait with any other known disease of sheep in affected flocks. Body condition scores for the thirteen sheep varied widely, from 1.5 (poor) to 3.0 (good), and this information, combined with the dietary history of the six affected flocks does not support any suggestion of a consistent nutritional effect. General physical examinations of the thirteen cases did not find any consistently concurrent illnesses, although respiratory disease (one case), foot rot (two cases), foot abscess (one case), dental wear (one case), mastitis (one case) and derangements of the fleece (three cases) were found. It may be argued that the presence of foot lesions in three cases may have affected the gait, but a neurological examination confirmed that forelimb paresis, rather than distal forelimb pain, was responsible for manifestation of the presenting signs.

Debate exists in the literature regarding the involvement of the Upper Motor Neurone (UMN) and the Lower Motor Neurone (LMN) systems in the manifestation of Kangaroo Gait. Down (1986) suggested UMN involvement, based on the neurological findings of Duffell and others (1986), which included paresis of voluntary motor function of the

forelimbs accompanied by intact spinal reflexes, and a lack of clinical evidence of reduced muscle bulk of the affected limbs. This theory may have been supported by the description of pathological changes in the central nervous system (CNS) by Barlow and Greig (1986), except that the variability of neurological signs demonstrated by the sheep examined in this study implied that more than one disease condition was present. UMN involvement was refuted by Wells and others (1986) who argued that axonal degeneration in the radial nerves in the absence of changes in the median and musculocutaneous nerves did not require changes in UMNs, and that such a pathogenesis was unlikely. This argument was supported by the pathological findings of Duffell and others (1986) and O'Toole and others (1989), who found changes in the radial nerves and the muscles supplied by them (mm. triceps brachii extensor carpi radialis), but not in the CNS. Results of a neurological examination of the thirteen sheep were variable, although bilateral forelimb extensor paresis was a consistent finding. Proprioceptive deficits were present in three moderately or severely affected animals, but were absent in other, more mildly affected sheep. Proprioceptive positioning may be deficient in patients with severe paresis (Delahunta, 1983), and deficits should be interpreted carefully in these sheep. Forelimb flexor withdrawal reflexes were intact for three cases. As suggested by Down (1986), this finding is consistent with UMN involvement, although it would also be consistent with a radial nerve neuropathy where efferent motor neurones (LMN) were preferentially affected and afferent nerve fibres were intact, or where crossover in interdigital cutaneous innervation from other peripheral nerves occurred. Efferent supply to the flexor muscles via the musculocutaneous, axillary, ulnar and median nerves would complete the reflex arc (Section 1.2.2.1.). It should also be noted that, according to Hoffmeyr (1978), the sheep is a poor subject for neurological examination, owing to the fact that the results of neurological examinations in clinically normal sheep were highly variable.

Conscious perception of noxious stimuli to the interdigital skin, as was apparent in the cases examined, indicates a functional sensory peripheral nerve, spinothalamic tract, and cerebral cortex. The muscles of the proximal forelimb appeared to be reduced in bulk on palpation in 10/13 cases. This may suggest muscle atrophy, although histopathology and morphometry performed on muscle biopsy samples would be required to demonstrate conclusively the presence of muscle atrophy. The radial nerve supplies the

main extensor muscles of the forelimb. Weakness and atrophy of these muscles would be consistent with a neuropathy of the radial nerve. The presence of forelimb hypermetria would also be consistent with relatively greater tone in the flexor muscles when compared to those extensor muscles supplied by affected radial nerves. In summary, the findings of neurological examinations in all thirteen sheep are consistent with a peripheral neuropathy or neuromuscular disorder affecting both radial nerves, although the possibility of UMN involvement cannot be ruled out.

Results of haematological investigations revealed consistent abnormalities in the neutrophil: lymphocyte ratio (10/12 cases). In three cases, this was associated with lymphopaenia, which may be a result of the depressing effects of corticosteroids associated with chronic disease (Jain, 1986). Chronic disease may also be responsible for the mild anaemia found in cases A and C (second sample). In two cases the abnormal neutrophil: lymphocyte ratio was associated with neutrophilia. Increased numbers of neutrophils may be associated with inflammation or stress, and corresponding reductions in percentages of lymphocytes is a relative, rather than an actual change (Jain, 1986). No other consistent abnormalities in haematology were found.

There were no marked abnormalities in biochemical parameters in any of the twelve cases tested, except in case M, where CK concentration was markedly increased. Increases in CK are associated with myopathies, neuromuscular disorders and disorders of the CNS (Kaneko and others, 1997). Increased AST concentrations may also be a non-specific indicator of disorders of the muscular and nervous tissues (Kaneko and others, 1997), and mild or moderate increases in the concentration of this enzyme were consistently found (7/12 cases). Aspartate aminotransferase lacks organ specificity, and has a high degree of activity in the liver (Kaneko and others, 1997). Increases in concentrations of other enzymes that may be associated with disorders of the liver were also found, including ALP (5/12 cases), GGT (3/12 cases), and GLDH (4/12 cases), although changes in these enzymes were generally mild. Mild decreases in blood calcium concentrations were found in 5/12 cases that may have been associated with the calcium demands of foetal ossification or lactation.

No consistent evidence of deficiencies or excesses of copper, selenium, vitamin E or vitamin B-12 were found in eleven cases of Kangaroo Gait. Results of virological investigations suggest that maedi-visna and border disease (viral diseases which affect nervous tissue in sheep) were not involved in the pathogenesis of Kangaroo Gait in these cases.

In summary, 13 cases of a locomotor disorder with a consistent and unique clinical presentation, affecting adult female sheep from six different flocks in South West Scotland, were examined. No obvious associations were found with unusual management practices, nutritional effects or intercurrent disease. No significant haematological, biochemical or virological abnormalities were consistently found. It was subsequently decided that a pathological investigation was warranted to define further the condition known as Kangaroo Gait.

CHAPTER 3

PATHOLOGICAL INVESTIGATIONS OF KANGAROO GAIT

3.1. INTRODUCTION

Few reports of pathological investigations of Kangaroo Gait have been published. Duffell and others (1986) described histopathological findings in two cases. Light microscopy of the radial nerves revealed Wallerian degeneration in a high proportion of peripheral nerve fibres, unaccompanied by changes in the Central Nervous System (CNS). Severe myopathy of the mm. triceps brachii and extensor carpi radialis was evident. Sarcocystosis, caused by sarcosporidia, was apparent in many muscles, including the heart. O'Toole and others (1989) reported the results of a more detailed pathological examination of these two cases. The main findings were: loss of myelinated axons in the radial nerves, the presence of numerous Renaut bodies, and evidence of regeneration of nerve fibres.

The pathological findings in six cases of Kangaroo Gait, reported by Barlow and Greig (1986) differed from those of the aforementioned studies. Light microscopy revealed spongy change and neuronal degeneration within the brain and spinal cord and ventral root ganglionopathy. Wallerian degeneration was evident in the radial nerves of 3/6 cases, accompanied by myopathy of the m. triceps brachii. Skeletal and cardiac muscle from 3/6 cases also had heavy infestations with sarcosporidia. An attempt was made to explain the variability of the findings by suggesting that radial nerve degeneration could be a later consequence of spongy change within the CNS. It is possible that the findings of this study are complicated by the presence of a number of disease entities, such as those discussed in Chapter 1, other than that which causes Kangaroo Gait.

The precise nature of pathological changes and specific techniques used for pathological examination were not described in an investigation of a similar locomotor disorder in three pregnant ewes reported by Clarkson (1991), although the pathological findings were described as 'typical' (for Kangaroo Gait).

It was decided to undertake a pathological investigation of clinically diagnosed cases of Kangaroo Gait at the University of Glasgow Veterinary School (UGVS). Onset of clinical signs in the three cases available at UGVS had occurred during late gestation. The aims of the pathological study were, therefore, to describe pathological changes in

the peripheral nerves, central nervous system, muscles and other body tissues in three cases of Kangaroo Gait where onset of clinical signs had been during late gestation, and to compare these changes with those reported in the literature.

3.2. MATERIALS AND METHODS

3.2.1. The Animals

Three Texel gimmers (cases A, B and C, section 2.2.) and their lambs were available for pathological examination. The worst affected of the gimmers (case A) was euthanased in April 1999, six weeks after arrival at the University of Glasgow Veterinary School (UGVS), while still pregnant. In late April 1999, one of the remaining gimmers (case B) lambed, followed by the other (case C) in early May. Both gimmers lambed twins, and the lambings were normal; however the lambs were small and weak, and they were euthanased soon after birth. After lambing, the affected gimmers began to demonstrate gradual clinical improvement in the severity of neurological signs. Case B was euthanased in May 1999, nine weeks after arriving at UGVS and three weeks after lambing. Case C was also euthanased in May 1999, seven weeks after arrival at UGVS and three weeks after lambing. The case records of the Scottish Mule that had been examined in April 1998 (case F, section 2.2.), were reviewed. This gimmer had been euthanased in September 1998, 24 weeks after lambing, and 18 weeks after arriving at UGVS. All animals were euthanased using intravenous injection of pentobarbitone sodium (Euthatal) (Rhone Merieux Ltd.) at the recommended dose.

3.2.2. Appropriation and Fixation of Pathological Material

Carcasses of all sheep were referred to the Department of Veterinary Pathology (Dept. Vet. Path.) at UGVS for pathological examination. A gross pathological examination was performed in all cases, and the findings recorded. From cases B, C and F, and from the two lambs of case C, brain, spinal cord, nerve root ganglia, radial nerve, sciatic nerve and optic nerve, were removed and fixed by immersion in buffered neutral formaldehyde, 4%. Peripheral nerves and spinal cord were weighted to maintain shape and structure. The brains of the adult sheep were dissected following immersion, and

sections of brain, including vestibular nuclei, oculomotor nuclei, hippocampus, red nuclei, and a section of cerebellum were submitted. One centimetre cubed sections of a selection of muscles from cases B, C and F were placed in buffered neutral formaldehyde, 4%. Muscles included extensor carpi radialis, triceps brachii, biceps brachii, biceps femoris, quadriceps femoris and semitendinosus. Samples of lung, liver, kidney and spleen were obtained, and fixed in buffered neutral formaldehyde, 4%.

Tissues from case A were fixed by intra-aortic perfusion with Karnovsky's modified fixative (paraformaldehyde 4%/glutaraldehyde 5%). Immediately following euthanasia, ten millilitres of heparin (Heparin injection BP) (Leo Laboratories Ltd.) was injected intravenously to prevent clotting. The sheep was placed in right lateral recumbency on a post mortem table. The left thoracic wall was removed to allow access to the aorta. A small incision was made into the dorsal aorta and a rubber tube was inserted through the incision and secured with a tie. An incision was made into the right auricle of the heart, to allow blood to escape. The vasculature was flushed with five litres of 0.85% saline, followed by eight litres of Karnovsky's modified fixative. The flow rate was approximately 13 litres per hour, and the head of pressure was approximately two metres.

Brain, spinal cord, nerve root ganglia, radial nerve and sciatic nerve from case A were removed by the routine procedures employed in the post mortem room at UGVS. These tissues were labelled and placed in pots of Karnovsky's modified fixative. Peripheral nerves and spinal cord were labelled and weighted as described above. The following sections of brain were dissected and submitted for pathological examination: vestibular nuclei, oculomotor nuclei, hippocampus, red nuclei, and a section of cerebellum.

3.2.3. Processing and Examination of Tissue Samples

Tissues from cases B, C and F, and the lambs of case C, were processed using Shandon Elliot automatic tissue processors (Histokinettes), and were subsequently embedded in paraffin wax. One centimetre lengths of every second spinal cord segment, lumbar and cervical dorsal root ganglia (DRG), multiple segments of radial, sciatic and optic nerve, and one centimetre cubed sections of body tissues, were processed in a 24 hour

histokinette. The dissected sections of brain from adult sheep (as described in section 3.2.3.) were processed in a seven day histokinette. Tissues were cut on a Biocut 2035 microtome (Leica) at four μm, mounted onto plain slides, and oven-dried at 60°C overnight. Sections were stained with haematoxylin and eosin (H&E), according to UGVS histopathology laboratory protocols, and mounted in DPX mountant (BDH).

From case A, sections of spinal cord, proximal, middle and distal portions of radial and sciatic nerves, and dissected sections of brain (as described in section 3.2.3.) were submitted. Tissues were processed using a Lynx *el* microscopy tissue processor (Leica) for embedding in Araldite resin. Sections were cut at one μm on an ultracut E ultratome (Reichert-Jung) and mounted on sulphuric acid-treated slides. Cut sections were stained with methylene blue/azure II to demonstrate myelin, employing UGVS histopathology laboratory protocols. Slides were heated on a hot plate to 60°C, flooded with stain for 10-30 seconds, and rinsed with running tap water. They were dried overnight on the hot plate and mounted in DPX mountant (BDH).

All slides were examined using light microscopy. Processing of araldite resin embedded sections was performed by Mr R. Blackley at the Dept. Vet. Path., UGVS and processing of paraffin wax embedded sections was performed in the histopathology laboratory at UGVS. Examination of slides was performed by Dr P. E. J. Johnston and Professor I. R. Griffiths at the Dept. Vet. Path., UGVS.

3.3. RESULTS

3.3.1. Gross Pathology

Carcasses of all adult female sheep were found to be in reasonable condition, based on an assessment of the amount of fat in each carcass. Footrot was evident in all four feet of case A. In case B, pinpoint lesions on the dorsal surfaces of the lungs were present, suggestive of *Muellarius capillaris* infection and there were small nodules on the surface of the abomasum consistent with *Telodorsagia circumcincta* infection. In case C, there was also indication of *T. circumcincta* infection in the abomasum, as well as evidence in the lungs of parasitic pneumonia caused by *Dictyocaulus filaria.* In case F

there were skin lesions over the pressure points of the forelimbs consistent with abnormal stance, the triceps brachii muscle appeared pale and flaccid, the mesenteric lymph nodes were slightly enlarged, and there was evidence in the lungs of a mild parasitic pneumonia. The carcasses of both lambs were emaciated.

3.3.2. Wax Paraffin Sections

No significant abnormalities were found in the sciatic, radial or optic nerves of case B, and no abnormalities were detected in the DRG. Changes in the spinal cord included: one degenerating axon (dorsal column of segments C2 and L4/5), two swollen axons (one in the ventral column of segment C4/5, one in the grey matter of the ventral horn of segment T4/5), and one small glial cell accumulation (ventral column of C8/T1). No changes were found in sections of the brain.

In case C, occasional degenerate axons were found in sections of the radial nerve. No significant abnormalities were seen in sections of the sciatic nerve. One chromatolytic neurone was found in the lumbar DRG. Changes in the spinal cord included: occasional myeloclasts (dorsal column and dorsal spinocerebellar tract of C4 and C6) and one swollen axon (ventral column of L2). Examination of brain revealed foci of vacuolation throughout the optic tract, and in the basis pedunculi of the midbrain. Symmetrical vacuolation was also found throughout the cerebellar white matter. The vacuolation in the optic tract, midbrain and cerebellum was most likely due to myelin sheath vacuolation. Foci of gliosis were found throughout the thalamus, most prominently adjacent to the central canal and mesencephalic aqueduct. Sections of the brain from case A were also fixed using wax paraffin, stained with H&E and examined under a light microscope. No abnormalities were detected.

Sarcocysts were found in most sections of muscles examined from cases B and C, accompanied by occasional foci of eosinophilic myositis. No abnormalities were detected in spinal cord segments, DRG, radial nerves or sciatic nerves in the lambs of case C. No significant abnormalities were found in sections of spleen, liver, kidney or lung in any of the sheep examined.

Records of histopathological examination of the radial nerves of case F state that Wallerian degeneration was present in both radial nerves, but that the changes were not extensive. Examination of the cervical spinal cord did not reveal any significant abnormalities.

3.3.3. Araldite Resin Embedded Sections

No significant abnormalities were localised in sections of radial nerve, sciatic nerve or cervical spinal cord. Examinations of the brain revealed only occasional increases in glial cell numbers.

3.4. DISCUSSION

Intra-aortic perfusion and araldite resin processing were undertaken with the aim of preparing tissues for electron microscopy. Thick-cut sections (of one μm) were first examined using light microscopy in order to identify areas of tissue destined for further examination using the electron microscope (Johnston, P.E.J., personal communication), however, due to a lack of significant abnormalities detected in the sections of peripheral nerve, spinal cord or brain examined from case A, there was no indication to do so.

Other than the sparse changes evident in the radial nerves of case C, no evidence was found of radial nerve degeneration in the three cases of Kangaroo Gait where onset of clinical signs had occurred during late gestation. It may be argued that these findings weaken the hypothesis that Kangaroo Gait can first occur during late gestation as well as lactation, and that a separate aetiopathogenesis for the two presentations is possible. Pathological examinations were not undertaken in these sheep until at least six weeks after arrival at UGVS, and at least nine weeks after the onset of clinical signs. Additionally, cases B and C were showing signs of clinical improvement preceding the time of euthanasia. It is possible, therefore, that radial nerve regeneration had obliterated the presence of any lesions by the time of submission to the Dept. Vet. Path. It remains true that there are few reports of the pathology associated with the onset of bilateral forelimb paresis in adult female sheep, either during late gestation or lactation. It is possible, therefore, that a spectrum of pathological changes in the peripheral nerves

of affected sheep exists, ranging from extensive Wallerian degeneration of the radial nerve to relatively little, or no, obvious change.

Histopathological examinations of the brains of two affected sheep did not reveal any pathological changes. Non-specific changes, including vacuolation and gliosis, were found in the brain of case C. Vacuolation is a feature of many metabolic and toxic conditions and lysosomal storage diseases, and gliosis may accompany Wallerian degeneration, neuronal loss, and sustained CNS oedema. Both are features of many viral encephalitides (Koestner and Jones, 1997). Barlow and Greig (1986) reported spongy change in the CNS of a number of sheep that suffered from locomotor disorders thought to resemble Kangaroo Gait, but no such changes were observed in this investigation. No evidence has been found to support the suggestion that CNS lesions play a role in precipitating changes in the peripheral nerves in Kangaroo Gait, however the possibility that this condition arises from a CNS disorder, with UMN dysfunction resulting in a locomotor disorder of the forelimbs, cannot be ruled out. The finding of non-specific changes in the spinal cord in two cases, and in the brain in one case, supports this hypothesis.

Sarcocystosis of affected sheep was a consistent finding in this study, as well as in the reports of Kangaroo Gait published by Duffell and others (1986) and Barlow and Greig (1986). Encephalitis and encephalomyelitis due to *Sarcocystis tenella* and other non-specific sporozoons have been reported, causing clinical signs of ataxia, fore- or hind-limb paresis, and flaccid paralysis, and pathological changes characteristic of non-suppurative encephalitis and myelitis (Morgan and others, 1984; O' Toole and others, 1986; O'Toole and others, 1993; Scott and others, 1993b; Henderson and others, 1997; Sargison and others, 2000). However, there are no reports in the literature of sporozoons invading or causing inflammation of specific nerves. Additionally, sarcocystosis is a common finding in neurologically normal sheep during post-mortem examination at UGVS (Johnston, P.E.J., personal communication).

Following the results of this study it was decided to undertake further work to determine the geographical distribution and annual occurrence of cases of Kangaroo Gait, and to

compile further data on the gender, age, breed, physiological state and environment of sheep affected with this condition.

CHAPTER 4

DEMOGRAPHIC STUDY AMONG VETERINARY SURGEONS OF NORTHERN BRITAIN

4.1. INTRODUCTION

Reports of the clinical and pathological findings of a small number of cases of Kangaroo Gait exist, defining this condition as a locomotor disorder of adult female sheep, with onset during lactation or late pregnancy, and recovery following the termination of lactation, achieved by weaning the lambs. Period prevalence within affected flocks was reported to be low (less than 1% per annum) (Duffel and others, 1986; Barlow and Greig, 1986; Down, 1986; Clarkson, 1991). In chapters 2 and 3, the findings of clinical and pathological investigations involving 13 sheep from six flocks, were described. Although a diagnosis of Kangaroo Gait was reached in all cases, based on the findings of a clinical examination, and the collection of an anamnesis consistent with those of reported cases, variations were found which implied that a spectrum of clinical and pathological changes might be associated with this condition. It was decided that information relating to a much larger number of cases was required before the range of clinical and pathological characteristics of Kangaroo Gait could be defined fully. In addition, since Kangaroo Gait was first described in New Zealand in 1978 by Moffat, and in the United Kingdom (UK) in 1986 by Duffel and others, little information has been gained on the economic importance or geographical distribution of this condition, and the aetiology remains obscure. No epidemiological investigations of this condition have been undertaken to date.

A necessary part of an epidemiological disease investigation is to count affected animals, and to relate the number, distribution and composition of populations of affected animals to the size, distribution and composition of the population at risk (Thrusfield, 1995). In other words, it is necessary to compare the demographic characteristics of the two populations. Demographic information can be obtained through a census, which is a count of all individuals in a population. Censuses are the only means of exactly measuring the distribution of a variable in a population, however they are often prohibitively expensive or impossible to conduct (Thrusfield, 1995). Alternatively, estimates of the distribution of a variable can be made to a desired degree of accuracy by obtaining data from a representative sample of the population (Levy and Lemeshow, 1991).

Questionnaires are the main instrument for data collection in censuses and are widely used in epidemiological studies (Vaillancourt and others, 1991; Bourque and Fielder, 1995). There are three basic types of questionnaire study, defined by the method by which they are administered, including personal interviews, telephone interviews and mail surveys (Dillman, 1978). Mail surveys tend to be the least expensive to implement, although, they can be much more time consuming to administer than telephone interviews, and response rates tend to be lower than for personal and telephone interviews (Dillman, 1978; Bourque and Fielder, 1995). A major source of error in estimates of the characteristics of populations obtained by questionnaire surveys is non-response. Considerable effort is made in designing and implementing questionnaire surveys in order to avoid non-responses. Attention should be paid to the format, the ordering and structure of questions, the selection of stationary and the method by which the questionnaire package is assembled. The inclusion of a carefully constructed cover letter and an addressed return envelope are essential in minimising numbers of non-responses (Dillman, 1978). Pretesting of the questionnaire is a necessary practice, undertaken in order to evaluate the design, the degree of understanding of each question, and the information provided by the responses (Vaillancourt and others, 1991). Additionally, the use of follow-ups, including postcard reminders, letters and replacement questionnaires, significantly increases response rates (Dillman, 1978).

It was decided to undertake a questionnaire-based mail survey of veterinary surgeons in Scotland and northern England in order to gain information relating to the condition known as 'Kangaroo Gait'.

4.2. MATERIALS AND METHODS

4.2.1. Considerations

It was decided that the term 'idiopathic forelimb paresis' (IFP) would be used in place of Kangaroo Gait for the purpose of this study. This decision was taken because it was thought that such an unambiguous and descriptive term would aid participants in recalling accurately the disease syndrome under investigation. It was decided to

nominate the flock as the sampling unit, where a flock having had one or more cases of IFP diagnosed by a veterinary surgeon, or reported to a veterinary surgeon by the flock owner, was considered affected. The flock, rather than the individual sheep was chosen as the sampling unit because it was considered unlikely that survey participants (veterinary surgeons) would be able to provide accurate information relating to individual animals. Additionally, variation in management, location and physical environment were predicted to be more significant between flocks than within flocks.

It was decided to implement a simple cluster sampling design, with veterinary practices serving as cluster units. This decision was taken for the following reasons:

1) There were no lists of sheep flocks readily available to the study. In contrast, The Directory of Veterinary Practices (Hall, 1997), which contains a list of veterinary practices providing veterinary care for sheep, was readily available.

2) A simple cluster sampling design maximised the number of flocks about which information could be gained, allowing for the strict limitations of financial and human resources made available to the study.

3) Involvement of veterinary surgeons was necessary for credible diagnosis of cases of IFP.

4) It was considered ethical to involve veterinary surgeons in the collection of information pertaining to the health status of sheep under their veterinary care.

It was decided that a census of all veterinary practices in the study area would be undertaken. This was largely due to a lack of information that prevented an estimation of the expected prevalence of Kangaroo Gait-affected flocks in the study area, information that was essential for calculating a required sample size (Levy and Lemeshow, 1991).

4.2.2. The Study Area

The selected study area included all parts of the island of Great Britain north of, and including, Lancashire and North Yorkshire, as well as the Isle of Man and the islands of Scotland (including the Hebrides, Orkney and Shetland). The size of the study area was restricted in order to accommodate the limited availability of financial and human

resources. Additionally, restricting the study to this area permitted recruitment of a relatively small number of veterinary surgeons, who could provide information relating to a large proportion of flocks within the United Kingdom. According to the 1999 June agricultural censuses of the Ministry of Agriculture, Fisheries and Food (MAFF), the Scottish Executive Rural Affairs Department (SERAD), and the Isle of Man Department of Agriculture Fisheries and Forestry (DAFF), the study area contained 17.9 million sheep (43.2 % of the total UK population), including 7.6 million breeding female sheep (40.0 % of the total UK population), kept on 27.0 thousand holdings (36.0 % of the total UK number) (all UK figures include the Isle of Man, and exclude Northern Ireland).

4.2.3. Recruitment of Veterinary Surgeons

Details of veterinary practices were obtained from The Directory of Veterinary Practices (Hall, 1997). According to the directory, 242 practices in the study area provided veterinary care for sheep. An electronic spreadsheet, including the names, addresses, and telephone numbers of all 242 practices was created using Microsoft Excel (Microsoft Corporation) software.

4.2.4. Questionnaire Design and Evolution

4.2.4.1. Format

The questionnaire was designed using Microsoft Word 6.0c (Microsoft Corporation) word processing software, and was printed on both sides of two sheets of standard A4 (210 x 297 mm) paper. Questionnaires were orientated using a landscape format, and were designed to be folded down the middle in the form of an eight-page booklet (148 x 210 mm), including front and back covers. The pages were bound with a single staple applied with a manual long-arm stapler. A title of 'Idiopathic Forelimb Paresis (Kangaroo Gait)' was decided, with an accompanying sub-title 'A Demographic Study Among Veterinary Surgeons of Northern Britain'.

The University of Glasgow logo (available in electronic format from the University of Glasgow) was placed in a central position at the top of the front cover, above the title

and sub-title. Below these was placed a digital photograph of a Scottish Mule gimmer with flexed carpi, supporting its weight on the dorsal surfaces of the metacarpi, converted from video analogue, using Apple QuickTime Videoplayer (Apple Computer Inc.) software, which was selected from footage taken at the University of Glasgow Veterinary School (UGVS). A brief introductory description of IFP was provided at the top of the inside front cover page, including a summary of the distinct presenting signs of IFP and the main neurological findings. Care was taken not to include terms that may have biased responses to questions presented in the document. Both the digital photograph and the description of IFP were provided as memory prompts to improve recollection of cases of this condition. All pages, excluding the front cover, were surrounded by a single-line border, located 1.5 cm from the external edges of each page, and 1.65 cm from the central fold. All questions were typed in Times New Roman font, 12 point characters, and lines were separated by 1.5 line spacings.

4.2.4.2. Questions

Questions were spaced evenly on each page, with sufficient space provided for those questions requiring written answers. Vertical continuity was established in alignment of question numbers, questions and spaces for written responses, to reduce the risk of inadvertent omissions by respondents. Prior to question one, an instruction was written which stated that all questions in the document related to sheep and flocks receiving veterinary care from the respondent's current practice only. This was to prevent respondents from providing information about flocks serviced by other practices in which they had worked previously.

Questions were aimed at obtaining the following information:

1) The number, size and predominant grazing systems (lowland, upland or hill) of flocks provided veterinary care by the respondent's practice.

2) Whether the respondent or the respondent's colleagues had examined any cases of IFP or had received any reports of IFP from sheep owning clients.

3) The genders, age groups and physiological states of sheep examined or reported to be affected with IFP.

4) The breeds and cross breeds affected with IFP.

5) The number of flocks predominantly managed under each type of grazing system in which one or more cases of IFP had occurred.

6) The annual occurrence and the year of the first diagnosis of IFP in the practice area.

7) The estimated average annual occurrence of IFP in affected flocks.

8) The opinion of the respondent regarding the importance of IFP to the local sheep industry and to the owners of affected sheep.

9) Whether the respondent would be willing to participate in further studies of the condition.

In the final draft, questions requiring a numerical response, usually relating to numbers of flocks, but also to the year of first diagnosis of IFP, were open-ended. The question that sought information relating to the breeds most commonly affected with IFP was also open-ended. Questions relating to diagnosis or receipt of reports of IFP, whether the respondent would be interested in participating further in the study, and whether the respondent would like to receive a summary of the results of the study, were all structured as simple yes/no questions. Questions relating to gender, physiological state, breed, average annual incidence and importance of IFP were presented in a closed-ended format.

4.2.5. The Accompanying Letter

The covering letter was produced using Microsoft Word 6.0c (Microsoft Corporation) software and was printed on a single sheet of A4 (210 x 297 mm), 90 GM^2 paper. The University of Glasgow logo and the mailing date were placed in the top right corner and the name and address of the survey participant were placed in the top left corner. A space was left for the subject's name to be hand-written at the top of the letter. The letter consisted of three paragraphs. The first paragraph explained the reason for undertaking the study, including the statement that '*little is known about the aetiology or epidemiology*' of IFP. The second paragraph explained how the respondent's practice had been selected, that responses from all practices (including practices which no longer provided veterinary care for sheep) were considered important, and that confidentiality of responses was assured. The final paragraph reiterated the importance

of the study, notified the respondent of a question in the questionnaire regarding further participation in the study, invited potential respondents to contact the author should they have any questions, and thanked the respondent in anticipation of receipt of a completed questionnaire. The address, telephone number and fax number of the Division of Farm Animal Medicine and Production (FAMP) of UGVS were positioned at the bottom of the page. The author's signature and the name of the subject were hand-written in blue ink to increase personalisation.

4.2.6. Pretesting The Questionnaire and Accompanying Letter

4.2.6.1. Peer Pretesting

Five senior members of the Division of FAMP, and the Comparative Epidemiology and Informatics research group (CEI) at UGVS were recruited for pretesting the questionnaire and accompanying letter. Each subject was invited to write comments about the content, structure and format of both documents, and the subject was subsequently interviewed to obtain an explanation of the comments made, and to record further suggestions about how the documents could be improved. A number of changes were incorporated following peer pretesting.

The cover letter was changed slightly, including simplification of some of the terminology and adding an email address to the contact details to increase the range of media by which potential respondents could communicate with the author. The size of the font was reduced to 10 point characters in order to make the letter more compact and aesthetically pleasing. Other minor changes included improvements in grammar and syntax.

Many changes were incorporated into the questionnaire. The address of the Division of FAMP was added to the bottom of the front cover, in case the cover letter and return envelope were lost, thereby preventing return of the questionnaire. The introductory description of IFP on the inside front cover page was changed from italics to normal Times New Roman font, because it was considered that italics were more difficult to

read. Capital letters were also used for the term *'Kangaroo Gait'* in order to maintain consistency with the accompanying letter.

All references to IFP or Kangaroo Gait among the questions were standardised to *'idiopathic forelimb paresis'*, once again to maintain consistency and to prevent confusion. In all questions which required an estimated numerical response, the wording of the question was made *'Approximately what number...'* to ensure that answers were given in numerical form, and the word *'number'* was emboldened to emphasise this point. In question two, the ranges for responses two and three were changed to 50-500 and 500-1000 breeding females, because it was thought that estimates of flock sizes using these 'rounder' parameters would be more accurate, considering that veterinary surgeons rather than flock owners were to provide the responses. Crofting was removed as an option from questions 3 and 12, because it was thought that it would be difficult to differentiate between crofts and hill farms. In question seven, responses four and five were replaced with a single option *'Before 1990'* because it was considered unlikely that respondents would be able to provide accurate information for the years prior to the last decade. Question eight was considered confusing and was completely reworded to an open-ended question relating to the average annual occurrence of IFP in affected flocks. Sheep dairy breeds were added to question ten. Question 11 was removed as it was thought to be confusing and beyond the scope of the study. In question 12, *'adult breeding ewes/gimmers'* was condensed to *'breeding female sheep'*, for the purpose of simplicity. In question 14, *'early pregnancy'* and *'after weaning'* were separated to form two options, and the options were then re-ordered chronologically.

Several additional changes were made to improve the grammar, spelling and syntax of the text. Various changes were also made to the format, including justifying the text to both the left and right margins, and re-designing each page so that the first line of the first question was placed 1.5 line spaces below the top border, and the bottom line of the bottom question was placed 1.5 line spaces above the bottom border. These changes were made in order to improve the appearance of the questionnaire, and necessitated changing the order of questions to facilitate the improved format.

4.2.6.2. Pretesting a Sub Sample of the Population

Twenty practices were selected using a stratified random sampling design, where the sampling unit was the veterinary practice and the stratum was the geographical region. The ten geographical regions were: South East Scotland (including the Borders, Central Scotland, Fife and the Lothians), Tayside, Grampian, Highlands and Islands, Strathclyde, Dumfries and Galloway, North East England (including Cleveland, Durham, Northumberland and Tyne & Wear), Cumbria, Lancashire and North Yorkshire. Regions were numbered from one to ten. Each practice in each region was allocated an identification number, consisting of the region number and an integer between one and *n*, where *n* equalled the number of practices within the region. The number of practices to be pretested from each region (n) was calculated using the formula:

$$n = (n / 242) \times 20$$

The value of n was rounded to the nearest whole number.

A number (equalling 'n' above) of random numbers were selected using a random number generator in Microsoft Excel (Microsoft Corporation), and practices from each region with corresponding identification numbers were selected for pretesting.

Each of the 20 practices was contacted by telephone to obtain the name of the veterinary surgeon most involved in providing veterinary care for sheep. This represented an effort to address the questionnaire to the most appropriate individual in each practice, and thereby to increase the response rate and to obtain the best information on how questionnaires would be completed in the main study. One person indicated that their practice no longer provided veterinary care for sheep. This practice was excluded from the study, and another practice from the same region was selected using the random number generator.

Each questionnaire was marked with the practice identification number to facilitate correlation between returned questionnaires and respondents. The contents and methods of folding the questionnaire package, and the methods of stamping and addressing

envelopes were identical to those described for the main study (section 4.2.7.). The first mailing took place on Monday, 12 July 1999. A postcard reminder was mailed to non-respondents on Tuesday, 20 July 1999 (Monday, 19 July was a public holiday, and no postal service was available). A follow-up telephone call was made to the remaining non-respondents three weeks after the initial mailing, in order to remind non-respondents to return the questionnaire, and if possible, to discover some of the reasons for why they had not done so. The 20 practices from which veterinary surgeons were recruited for pretesting the questionnaire were subsequently excluded from the rest of the study, and the responses were not included in the calculation of results.

4.2.6.3. Results of Pretesting and Formulation of the Final Draught

Veterinary surgeons from 17/20 practices (85%) returned a completed questionnaire. In question two, respondents indicated that 78 percent of flocks had 50-500 breeding female sheep. Additionally, most responses for options one and two comprised obviously rounded numbers. For this reason it was decided to change the ranges for options two and three to 50-250 and 250-500 breeding females. Many respondents provided a tick in response to questions four and five. It was therefore decided to place a prompt requesting respondents to circle the number adjacent the appropriate response at the end of each question. Question seven was changed from an open-ended question requesting percentages to an unordered closed-ended question, with additional options for early and mid/late lactation and barren ewes. The sample unit for this question was changed from the individual sheep to the flock in order to maintain consistency with the rest of the study. Question ten was answered poorly, with responses including integers, ranges and percentages. The wording of this question was changed to emphasise the requirement of a numerical response. In question 12, it was decided to add an option for 1997 as several respondents indicated that they had first diagnosed a case of IFP in that year. Additionally, responses to options three and four were difficult to analyse owing to the required unit of the response (average cases per year). The unit was changed to total number of cases for each time period. Question 13 was poorly answered, with respondents using either ranges or a rounded response. It was decided to change the design of this question to an ordered closed-ended format, with six options, each comprising a percentile range with a corresponding ratio of affected to non-affected

sheep. The format of question 14 was changed to place option numbers closer to the corresponding response. A sixth *'unsure'* option was also added due to several indications by respondents that they were unsure of the economic importance of this condition. A final draught of the questionnaire can be found in Appendix 6. The accompanying letter was not changed as a result of further pretesting and the final draught was therefore the same as that in Appendix 7.

4.2.7. Mailing the Questionnaire to the Subjects of the Study

4.2.7.1. The First Mailing

Each mailing package contained the questionnaire, the accompanying letter, and a white return envelope (size 110 x 220 mm), stamped with a first class commemorative stamp. The package was enclosed in a white outer envelope (size 110 x 220 mm), stamped with a first class commemorative stamp, and addressed with self-adhesive labels. Address labels were created using the mailmerge tool of Microsoft Word 6.0c (Microsoft Corporation), taking details from a Microsoft Excel (Microsoft Corporation) spreadsheet of practice addresses, which excluded the 20 practices recruited for pretesting. The three components were folded in thirds, with the questionnaire and letter placed together inside the accompanying letter in such as fashion that all three components had to be removed from the outer envelope together. Envelopes and accompanying letters were addressed to individual veterinary surgeons, the names of which were selected from The Directory of Veterinary Practices (Hall, 1997). It was impossible to know whether the most appropriate member of the practice was selected, although attempts were made to target senior members of each practice by selecting those veterinary surgeons that graduated earliest.

All 221 mailing packages were posted on Monday, 9 August 1999. As questionnaires were returned the date of receipt was recorded on the front cover.

4.2.7.2. The Postcard Reminder

A reminder was posted to 168 non-respondents on Tuesday, 17 August 1999 (Appendix 8). This reminder was printed on both sides of 110 x (approximately) 99mm, 160 GM^2, light yellow or light green card, in the format of a postcard. The postcard was designed using Microsoft Word 6.0c (Microsoft Corporation) software. The University of Glasgow crest was placed on the left side of the front of the card, and the title of the study was placed in the centre of the front side of the card, above the digital photograph of the Scottish Mule gimmer, above the address of the Division of FAMP. On the rear side of the postcard a short message was written. The first paragraph reminded the respondent that a questionnaire had been posted in the previous week. In the second paragraph, thanks were given to those respondents who had returned the questionnaire, and a prompt was given to those respondents who had not returned the questionnaire to do so. The postcards were individually addressed, with the name of the respondent and the signature of the author hand-printed in blue ink. The postcard was placed inside a white envelope (110 x 220 mm), with a regular first class stamp affixed. A separate spreadsheet of non-respondents was created and self-adhesive address labels were printed in the same fashion as those for the first mailing (4.2.7.1.).

4.2.7.3. The Final Mailing and Follow-Ups

A second mailing package was posted to 70 non-respondents on Tuesday, 14 September 1999. This mailing package consisted of a questionnaire, a returned envelope with a commemorative stamp affixed, and an accompanying letter, all folded and enclosed in an outer envelope in the same fashion as the first mailing package (4.2.7.1.). A separate spreadsheet of non-respondents was created for the production of self-adhesive address labels. The purpose of the accompanying letter was to remind the potential respondent that a completed questionnaire had not yet been received from them (Appendix 9).

Two to three weeks after the final reminder was posted all remaining non-respondents were telephoned and simply asked if their practice still provided veterinary care for sheep. This was done in order to calculate a final response rate among practices that provided veterinary care for sheep.

4.2.8. Database Design

A Microsoft Access (Microsoft Corporation) database table was designed to store data for this study. All data were stored in a single table, with one database field corresponding to each response. Simple analyses and transformation of data were carried out in Microsoft Access using specifically designed queries. Further analyses were carried out making use of data analysis tools in Microsoft Excel (Microsoft Corporation) after data had been imported from the Microsoft Access database. Where appropriate, chi-square analyses and chi-square comparisons, using the Bonferroni method (Petrie and Watson, 1999), were undertaken, using Minitab 12 for Windows (Minitab Inc.) software. Chi-square tests with P-values less than 0.05 were considered to demonstrate significant differences.

4.3. RESULTS

4.3.1. Response

Of the 221 practices surveyed, respondents from 15 indicated that their practice did not provide veterinary care for sheep, and three indicated that their practices had been merged with other practices or had been sold. From the remaining 203 practices, 174 respondents returned questionnaires before the final date (two questionnaires were returned in November, 1999, but the responses were not included in these results). Two questionnaires were completed inadequately, leaving 172 useable responses. The useable response rate among potential respondents from practices providing veterinary care for sheep was, therefore:

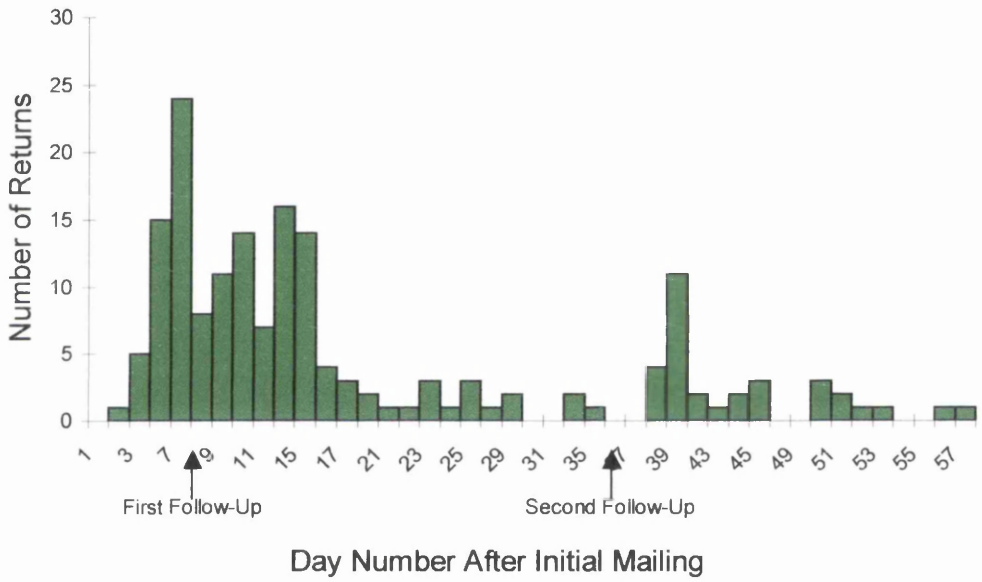
$$172/203 \times 100 = 84.7\%$$

Table 4.1. Shows the usable response rates following the original and the two follow-up mailings in this study. Figure 4.1. Shows the daily number of useable returns following the initial mailing.

Table 4.1. Percentages of respondents, from practices that provided veterinary care for sheep, returning usable questionnaires after each mailing.

Mailing	Percentage of Respondents Returning Usable Questionnaires
Initial Mailing	26.1
First Follow-Up	42.3
Second Follow-Up	16.3

Figure 4.1. Number of returns per day after the initial mailing.



Note: Saturdays and Sundays are excluded from the X-axis

4.3.2. Survey Data

4.3.2.1. The Population at Risk

One hundred and seventy-one respondents answered questions one, two and three. The summary statistics for responses to question 1, which pertained to the total number of flocks for which respondent's practices provided veterinary care, are provided in table 4.2. In total, the respondents indicated their practices provide veterinary care for 14 656

flocks. The number of flocks for which individual practices provided veterinary care ranged greatly. In Table 4.3., the flocks are categorised by numbers of breeding females in each flock. Responses to question 2, pertaining to the number of flocks in the practice area in each size category, indicated that the size category with the greatest number of flocks was 50-250 breeding females (5 569 flocks), followed by 250-500 breeding females (4 097 flocks), >500 breeding females (2 798 flocks) and <50 breeding females (2 203 flocks). In Table 4.4., the flocks are categorised by predominant grazing system (question 3), defined by topographic type ('lowland', 'upland', 'hill' or 'other'). The production system under which the greatest number of flocks was managed was upland (5 582 flocks), followed by hill (4 595 flocks), lowland (4 347 flocks) and other (57 flocks). 'Other' farm categories included hobby (2 respondents, 21 flocks), moor (1 respondent, 20 flocks), crofts (1 respondent, 15 flocks), and research (1 respondent, 1 flock).

In Table 4.5., the numbers of practices and flocks in each region for which responses were obtained in the survey, were summarised, in addition to the number of flocks for which responses were obtained as a percentage of the total number in each region, according to the June agricultural censuses of the Ministry of Agriculture, Fisheries and Food (MAFF), the Scottish Executive Rural Affairs Department (SERAD) and the Isle of Man Department of Agriculture, Fisheries and Forestry (DAFF). The number of respondents in each region ranged from three (Durham, Cleveland and Isle of Man) to 31 (Strathclyde). The number of flocks ranged from 61 (Fife) to 3 364 (Highlands and Islands). The regions from which information was gained on the smallest and greatest percentages of flocks were Fife (27.4%) and Cleveland (111.4%) respectively.

Figure 4.3. shows the number of flocks in each region grouped by flock size, and Figure 4.4. shows the number of flocks in each region grouped by predominant grazing system. The region with greatest number of flocks comprised of <50 and 50-250 breeding females was the Highlands and Islands (632 and 1 716 flocks respectively). The region with the greatest number of flocks comprised of 250-500 breeding females was North Yorkshire (661 flocks) and the region with the greatest number of flocks comprised of >500 breeding females was Strathclyde (446 flocks). The region with the greatest number of hill and upland flocks was the Highlands and Islands (1 278 and 1 681 flocks

respectively), and the region with the greatest number of lowland flocks was North Yorkshire (777 flocks). The structure of the sheep industry, both relating to flock size and predominant grazing system, varied considerably between the regions in this survey. For example, the Scottish Borders contained predominantly large flocks (>500 breeding females), managed on upland pastures, whereas the Grampians contained predominantly small flocks (<50 and 50-250 breeding females), managed on lowland pastures, and the Highlands and Islands contained predominantly small flocks (<50 and 50-250 breeding females), managed on upland and hill pastures.

Table 4.2. The number of flocks provided veterinary care by each practice.

Descriptive Statistic	Result
Mean	85.7
Standard Error	9.6
Median	54
Mode	30
Standard Deviation	125.7
Range	1 199
Minimum	1
Maximum	1 200
Sum	14 656

Table 4.3. The number of flocks provided veterinary care by each practice categorised by numbers of breeding females in each flock.

	Flock Size Categories (Number of Breeding Females)			
Descriptive Stat.	**<50**	**50-250**	**250-500**	**>500**
Mean	13.0	32.8	24.0	16.4
Standard Error	1.9	5.4	2.6	2.1
Median	5	15	10	7
Mode	0	0	0	0
Standard Deviation	25.1	71.0	33.4	28.1
Range	200	800	200	200
Minimum	0	0	0	0
Maximum	200	800	200	200
Sum	2 203	5 569	4 097	2 798
Count	170*	170*	171	171

* Note: One respondent indicated they did not know how many flocks were serviced by their practice with less than 250 breeding females, hence the counts of 170 responses for the two relevant categories.

Table 4.4. Summary of descriptive statistics relating to numbers of flocks provided veterinary care by each practice, categorised by production systems (topographic types).

	Production System Categories			
Descriptive Stat.	**Lowland**	**Upland**	**Hill**	**Other**
Mean	25.4	32.6	26.9	0.3
Standard Error	2.8	5.3	4.1	0.2
Median	15	11	10	0
Mode	0	0	0	0
Standard Deviation	36.7	69.4	53.1	2.4
Range	300	750	450	20
Minimum	0	0	0	0
Maximum	300	750	450	20
Sum	4 347	5 582	4 595	57
Count	171	171	171	171

Table 4.5. The number of practices and flocks for which responses were obtained and the percentage of the total number of flocks as determined by the June agricultural censuses (MAFF, SERAD, DAFF), in each region.

Region	Number of Respondents	Total Flocks (Survey)	Total Flocks (Census)	Percentage of Flocks For Which Responses Were Obtained
Scottish Borders	4	458	992	46.2
Central Scotland	6	407	441	92.3
Dumfries & Galloway	13	1 025	1 598	64.1
Fife	3	61	223	27.4
Grampian	17	940	1 813	51.8
Highlands & Islands*	12	3 364	5 428	62.0
The Lothians	7	229	306	74.8
Strathclyde	31	1 589	2 419	63.8
Tayside	10	679	886	76.6
Cumbria	16	1 497	3 965	37.8
Cleveland	3	245	220	111.4
Durham	3	695	1 022	68.0
Lancashire	15	709	1 813	39.1
North'land & Tyne**	7	631	1 693	37.3
North Yorkshire	22	2 007	4 070	49.3
Isle of Man	3	120	129	93.0
Total	172	14 656	26 998	54.3

* Includes The Highlands, The Western Isles, Orkney and Shetland

** Includes Northumberland and Tyne and Wear

Figure 4.2. The number of flocks in each region grouped by numbers of female breeding sheep.

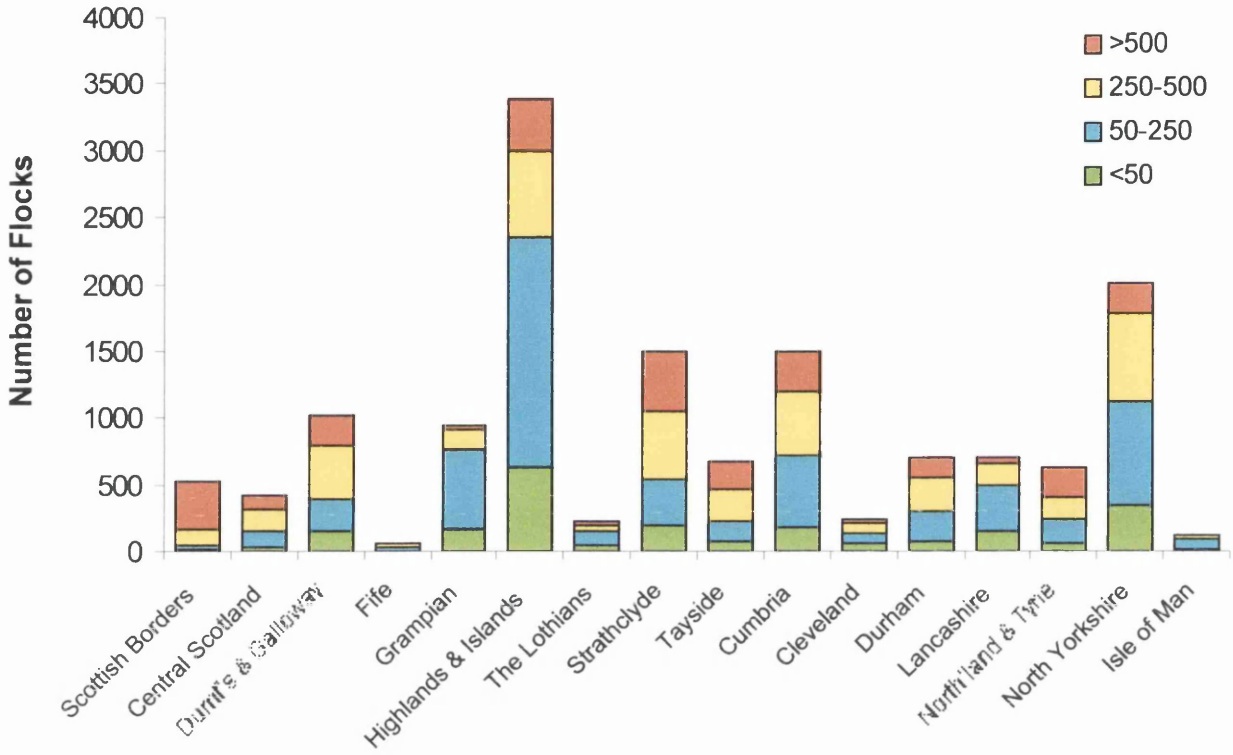
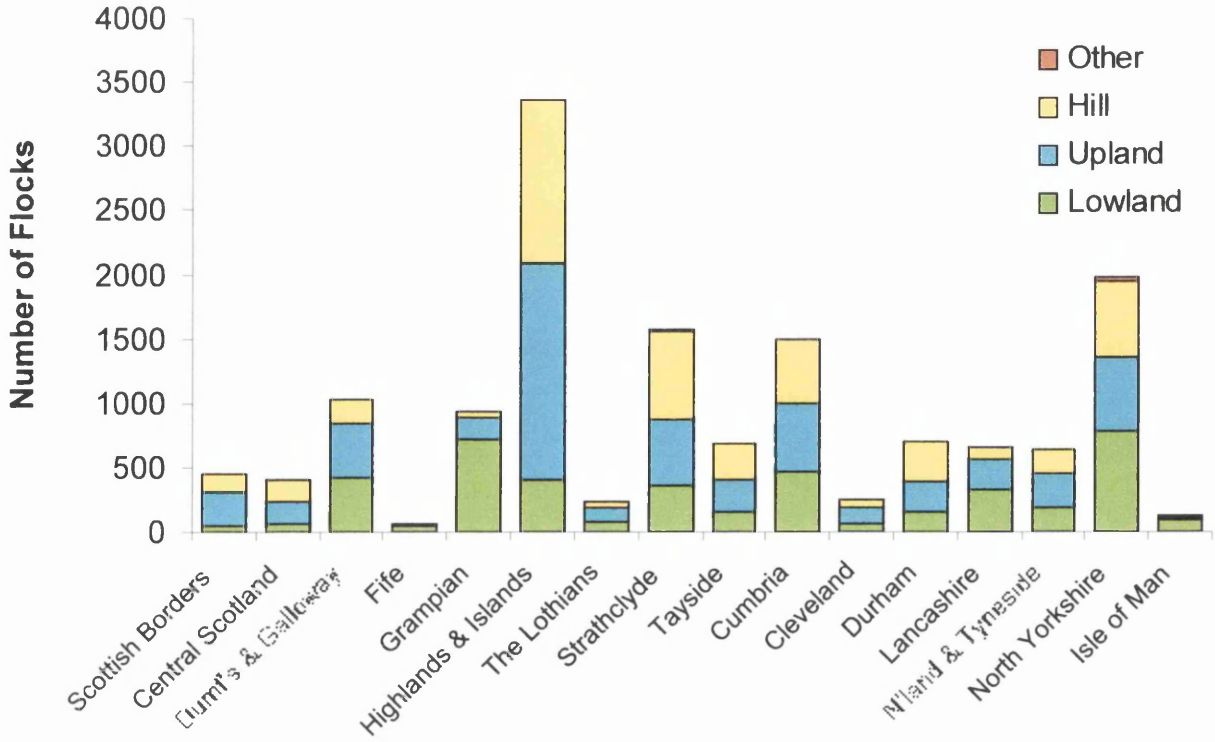


Figure 4.3. The number of flocks in each region grouped by production system (topographic type).



4.3.2.2. Flocks Affected By Kangaroo Gait

All 172 respondents responded to question 4. Table 4.6. summarises the responses to this question, indicating that veterinary surgeons from 46 practices (26.7%) had examined cases of IFP. All 126 respondents who indicated that they had not examined cases of IFP responded to question 5. Table 4.7. summarises the responses to this question, indicating that 4.0% of respondents who had not examined cases of IFP, had received reports of cases of IFP from their sheep owning clients. In total, 51 respondents had examined or received reports of cases of IFP (29.7% of all respondents). The geographical distribution of practices in which cases of IFP have, and have not, been identified, is represented in figure 4.4. From this map it is apparent that cases of IFP have occurred throughout the study area. Although no statistical analyses were performed, it appears that there is a greater concentration of practices from which cases have been identified in the Southern and Central regions of Scotland, and bordering areas in the North East of England. Figure 4.5. shows the number of respondents who answered 'yes' to questions four and five, and the number of respondents who answered 'no' to both questions, in each region. The regions with the greatest number of respondents who answered yes to questions four and five were Strathclyde and Cumbria (14 respondents and 2 respondents respectively). The region with the greatest proportion of respondents who answered 'yes' to either question was the Scottish Borders (100% of respondents answered 'yes' to question four). Cleveland was the only region from which no respondents answered 'yes' to either questions four or five.

The responses of one respondent from North Yorkshire, who indicated that they had examined cases of IFP, were subsequently excluded because sufficient evidence was found, including a description of cases provided in the comments section of the questionnaire, to suggest that animals examined were not indeed cases of IFP, but cases of perinatal trauma. Of the 50 remaining respondents who indicated they had examined or received reports of IFP, almost all (96.0%) indicated they had examined or received reports of IFP in adult female sheep. A small number indicated that they had examined or received reports of cases of IFP in other types of sheep, including tups, lambs and adult wethers (Figure 4.6.). Most respondents indicated that they had examined or

received reports of IFP in adult female sheep with onset either during early or mid/late lactation (52.0% and 44.0% respectively). A significant number indicated that they had examined or received reports of cases with onset during late pregnancy (22.0%), and a small number examined or received reports of cases with onset during early pregnancy (4.0%) or between weaning and tupping (2.0%) (Figure 4.7.).

Respondents indicated they had examined or received reports of IFP from a total of 58 lowland flocks, 61 upland flocks and 22 hill flocks (Table 4.8.), equating to a total of 141 flocks. The proportions of flocks affected with IFP differed significantly between lowland, upland and hill flocks ($P < 0.01$). There was no significant difference in the proportions of affected flocks managed under lowland and upland production systems, but a significantly lower proportion of hill flocks were affected ($P < 0.001$). Affected flocks accounted for 0.97% of the total number of flocks in the study area.

The greatest number of respondents that indicated that a specific breed or cross breed was most commonly affected was 18 (36.0%) for both the Greyface Mule and the Scottish/English Mule (Table 4.9.). Thirty-nine respondents (78.0%) indicated they had examined or received reports of cases of IFP in sheep from commercial cross breeds, 15 (30.0%) from hill breeds, ten (20.0%) from Texels and Texel crosses, nine (18%) from Suffolks and Suffolk crosses, and smaller numbers from other native and European lowland breeds and crosses (Figure 4.8.).

Respondents from three regions indicated they had first diagnosed a case of IFP before 1980 (Dumfries and Galloway, 1976, Tayside, 1978 and the Highlands and Islands, 1979), and respondents from one region (Fife) indicated that the first case of IFP had been diagnosed as recently as 1999. The years in which the first case of IFP had been diagnosed in each region are listed in Table 4.10. Table 4.11. shows the number of flocks from which one or more cases of IFP had been examined or reported, in each time period. At least 33 flocks were affected in the each of the years 1997-1999, with an average annual number of 9.7 flocks affected in the years 1990-1996 and an average annual number of 1.7 flocks in the years between the first recorded case (1976) and 1989. Twenty-two (44.0%) respondents indicated that the average percentage of adult female sheep in IFP affected flocks in years in which one or more cases had occurred

was <0.2%. In total, 39 respondents (78.0%) indicated that, on average, less than 0.5% of the flock was affected. Only eleven respondents (22.0%) indicated that, on average, 0.5-2.0% of the flock was affected, and no respondents indicated that, on average, greater than 2.0% of the flock was affected (Figure 4.9.).

One hundred and sixty-five respondents answered question 14, which sought the respondent's opinion of the economic importance of IFP (Figure 4.10.). In total, 121 respondents (73.3%) indicated that IFP was of little or no economic importance to their local sheep industry (responses three, four and five), and only six respondents (3.6%) indicated that IFP was of great or moderate economic importance (responses one and two). In reference to owners of affected sheep, however, 28 respondents (17.0%) indicated that IFP was of great or moderate economic importance (responses one, two and three), and 71 respondents (43.0%) indicated that IFP might have been of some economic importance (response four). Thirty-nine respondents (23.6%) indicated that they were unsure of the economic importance of this condition.

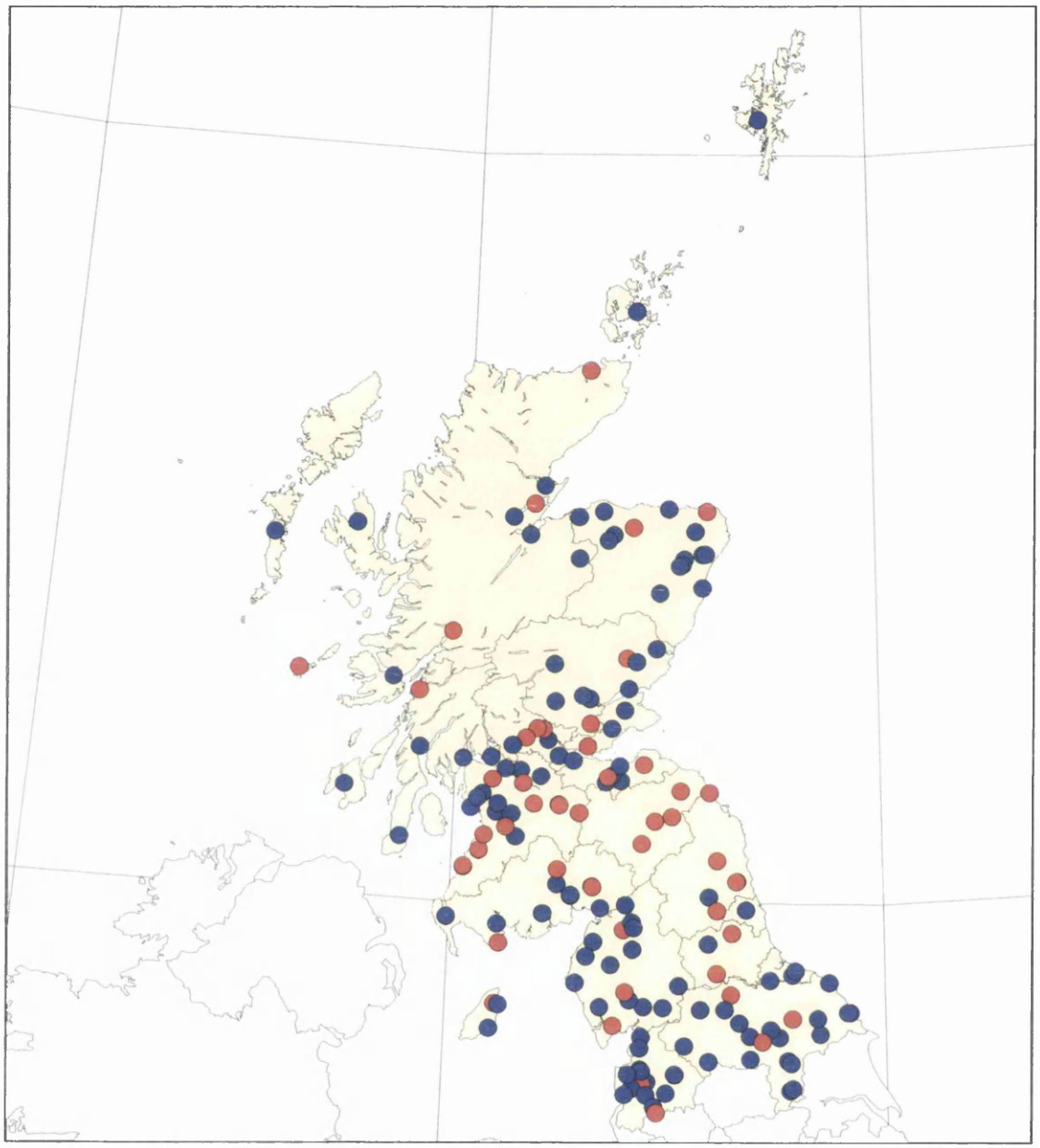
Table 4.6. Responses to question four: Does the respondent recall examining cases of IFP?

Response Category	Percentage of Responses (%)
No	73.3
Yes	26.7

Table 4.7. Responses to question five: Does the respondent recall receiving reports of IFP?

Response Category	Percentage of Responses (%)
No	96.0
Yes	4.0

Figure 4.4. Geographical distribution of veterinary practices in northern Britain where cases of IFP have, and have not, been identified.



Key:

- Practices where cases of IFP have been identified.
- Practices where no cases of IFP have been identified.

Figure 4.5. Responses to questions four (whether the respondent recalls examining cases of IFP), and five (whether the respondent recalls receiving reports of IFP), categorised by region.

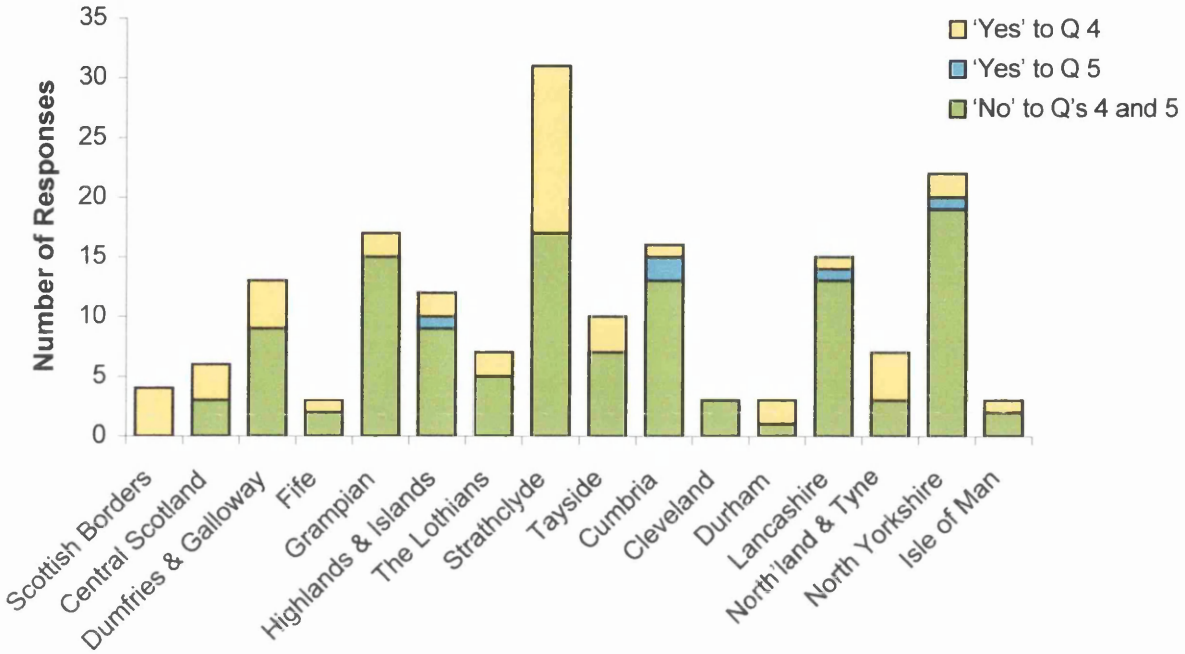


Figure 4.6. Number of respondents who had examined or received reports of IFP in each type of sheep.

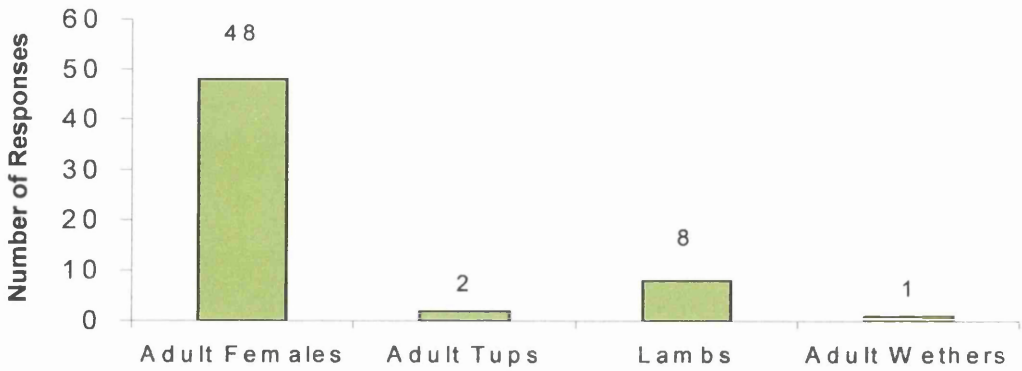


Figure 4.7. Number of respondents who had examined or received reports of IFP in adult female sheep in each physiological state.

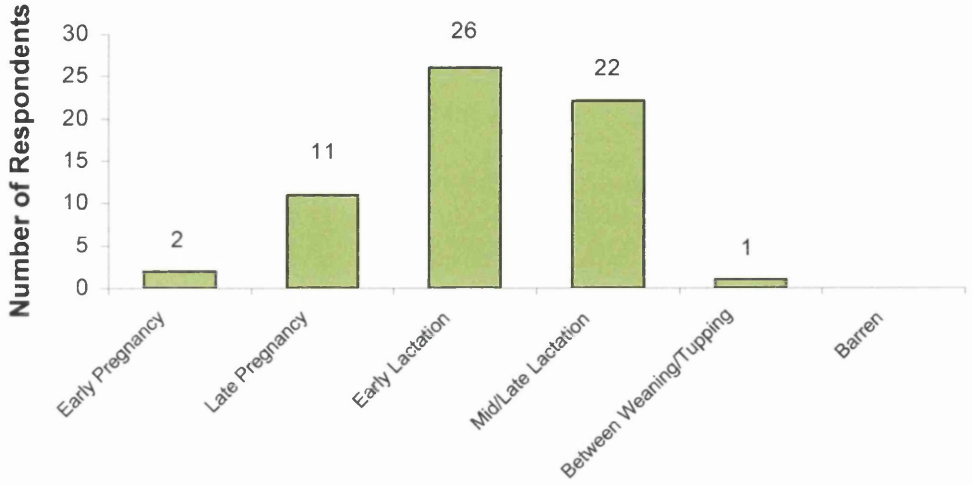


Table 4.8. Number of flocks managed under each production system (topographic type) that had been affected by and not affected by IFP.

Production System (Topographic Type)	Total Number of Flocks Affected	Total Number of Flocks Not Affected
Lowland	58	4 289
Upland	61	5 521
Hill	22	4 573

Table 4.9. Number of respondents indicating from which breeds or cross breeds cases of IFP had been most commonly examined or reported.

Breed or Cross Breed	Number of Respondents
Greyface Mule	18
Mule (Scottish or English)	18
Scottish Blackface	7
Halfbred	6
Texel	6
Cheviot	4
Suffolk	4
Swaledale	4
Suffolk cross	3
Texel cross	3
Border Leicester cross	2
Rouge de l'Ouest	2
Scottish Blackface cross	2
Bleu de Maine	1
Masham	1
Swaledale cross	1

Figure 4.8. Number of respondents who had examined or received reports of IFP in sheep from each breed or cross breed group.

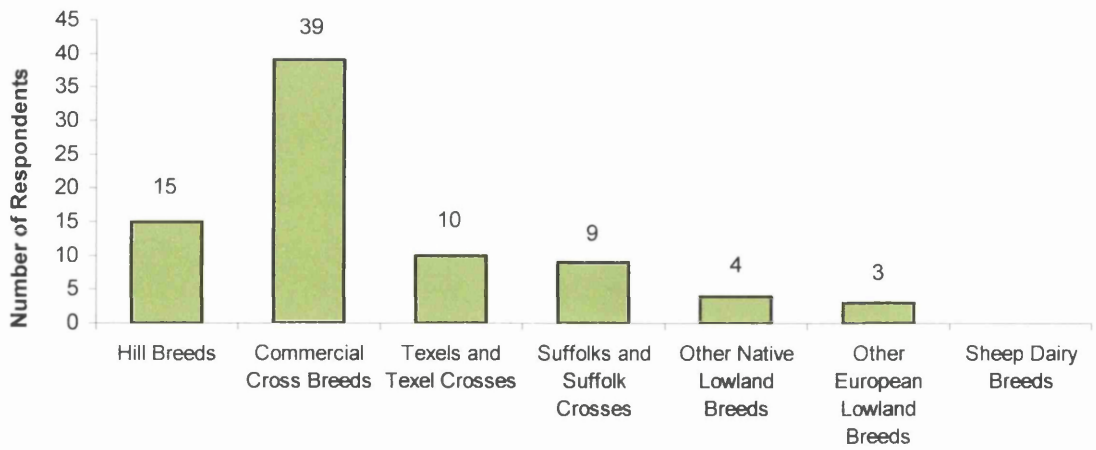


Table 4.10. The first year in which a case of IFP had been examined or reported in each region.

Region	Year
Dumfries & Galloway	1976
Tayside	1978
Highlands & Islands	1979
Grampian	1980
The Lothians	1980
Scottish Borders	1980
Central Scotland	1987
Cumbria	1989
Lancashire	1990
North Yorkshire	1990
Northumberland & Tyneside	1990
Strathclyde	1990
Durham	1996
Isle of Man	1996
Fife	1999

Table 4.11. Number of flocks that had been affected by IFP in each time period.

Time Period	Number of Flocks Affected
1999	33
1998	42
1997	36
1990-1996	68
Before 1990	22

Figure 4.9. Number of responses in each category relating to the average percentage of the flock affected by IFP in years in which one or more cases had occurred.

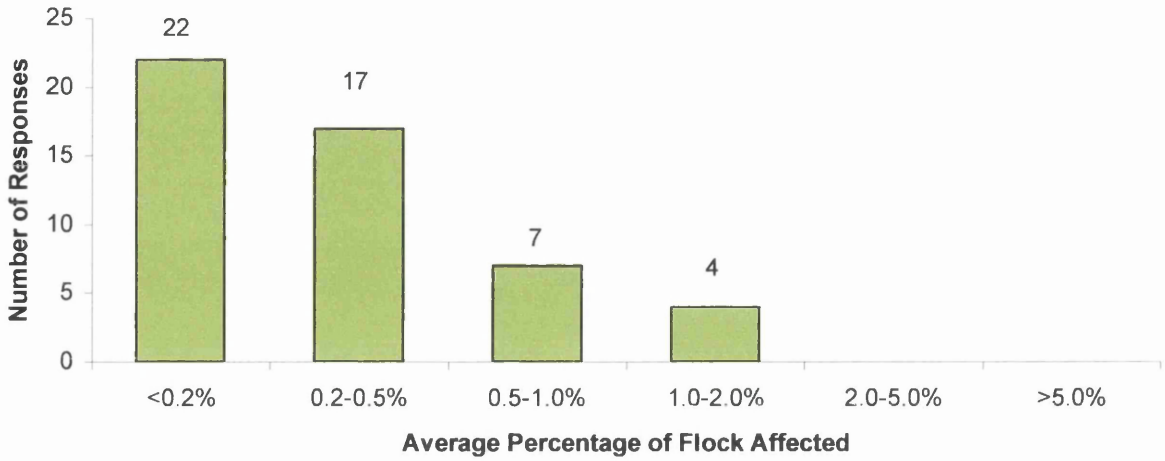
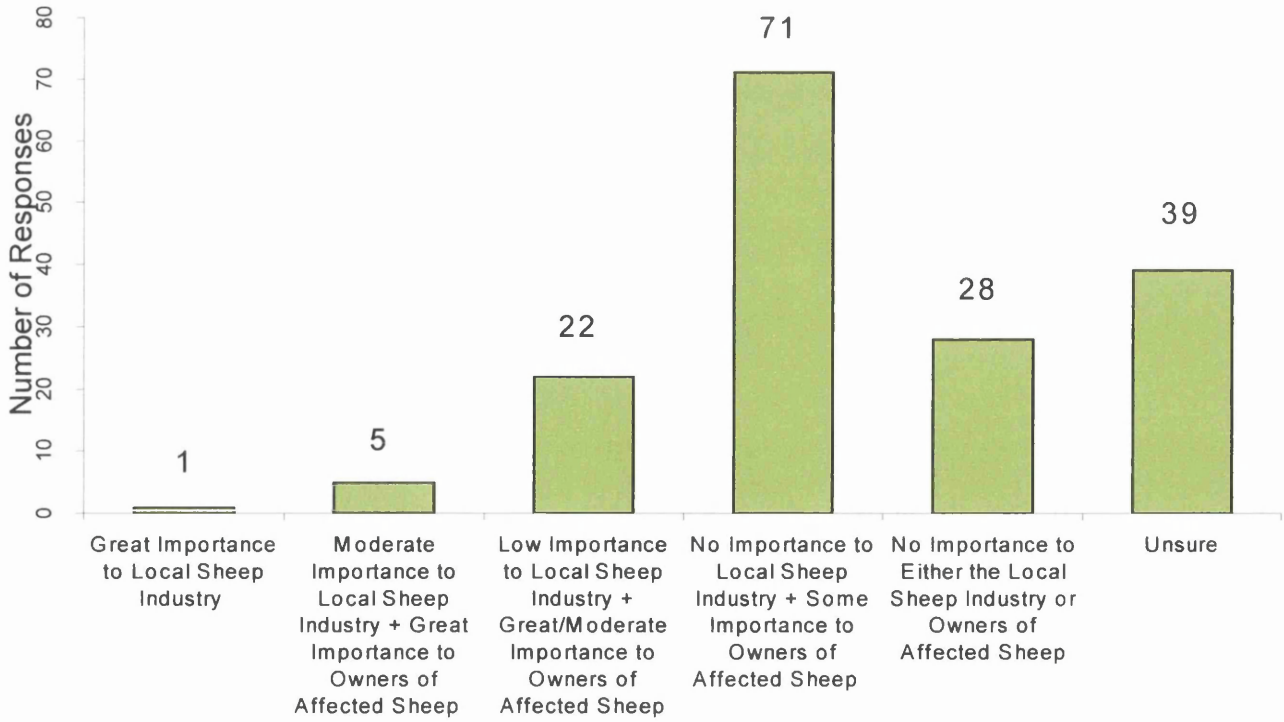


Figure 4.10. Number of respondents who indicated which statement best described the economic importance of IFP.



4.4. SUMMARY

A high useable response rate was obtained (84.7%), with information being gained on 14 656 flocks, cared for by 172 veterinary practices. Most flocks (65.9%) had between 50 and 500 breeding females, and there was a similar number of lowland, upland, and hill flocks (29.8%, 38.3% and 31.5% respectively) in the study area. The number, predominant size and grazing system of flocks varied widely between regions.

Over one quarter of respondents indicated that members of their practice had examined or received reports of at least one case of IFP (26.7%). Idiopathic Forelimb Paresis had been identified in all regions except Cleveland, and it appeared that there was a greater concentration of practices in which cases had been identified in the Southern and Central regions of Scotland and the bordering areas of North East England. Of the 50 respondents who indicated that members of their practice had examined or received reports of IFP, almost all (96.0%) indicated that affected animals included adult female sheep. A small number indicated that they had examined or received reports of IFP affecting tups, lambs and adult wethers. A high proportion of respondents indicated that adult female sheep had been affected during early and mid/late lactation, with fewer numbers of respondents indicating that adult female sheep had been affected during late pregnancy, early pregnancy and between weaning and tupping. Commercial crosses appeared to be the most commonly affected breed group among sheep in this study, with the Greyface Mule and the Scottish/English Mule being the breeds most commonly identified as being affected. Out of the 14 656 flocks in the study area, an estimated number of 141 flocks (0.96%) had been affected, and a significantly greater proportion of lowland and upland flocks were affected than hill flocks. The first case of IFP had been diagnosed in Dumfries and Galloway in 1976. Since then it appears that the average annual number of flocks identified as being affected has risen from approximately 1.7 (1976-1989), to 9.7 (1990-1996), to greater than 30.0 (1997-1999). The majority of respondents (78.0%) indicated that in years during which IFP occurred, it affected, on average, less than 0.5% of the number of adult female sheep in the flock. All remaining respondents indicated that it affected between 0.5 and 2.0% of the flock. In general, respondents indicated that IFP was not economically important to their local

sheep industries, but the majority (60.0%) considered IFP to be at least of some economic importance to owners of affected sheep.

4.5. DISCUSSION

This study represents the first recorded investigation of Kangaroo Gait relating to a large number of affected flocks. The study was considered to be demographic in nature because descriptive information was sought pertaining to the number, characteristics and environments of groups of individuals (flocks affected with IFP, and flocks at risk). Hypotheses based on prior observations of affected flocks were not tested and no attempt was made to determine risk factors for disease occurrence. The previously described reasons for selecting the term 'Idiopathic Forelimb Paresis' (section 4.2.1.) pertain specifically to the requirements of this study. It is not suggested that IFP should become a widely accepted alternative for the naming of the condition known as Kangaroo Gait.

A high response rate was achieved, reflecting the amount of time and effort spent in extensively pretesting the questionnaire and persisting with carefully timed and constructed follow-ups. A large percentage of respondents returned questionnaires after receiving the reminders (Table 4.1.). However, the first (postcard) reminder was posted only eight days after the initial mailing, and it is possible that many participants who responded at this time may have responded to the initial mailing regardless of receiving the reminder. Despite the success in achieving a high response rate, non-responses, accounting for 15.3% of the total number of potential returns, may have represented a potential source of bias in the survey results. This would be the case, for example, if non-respondents were more likely than respondents not to have examined or received reports of IFP. Similarly, if cases that had been examined or reported were atypical (possibly affecting males, lambs, or non-reproductive females), and were subsequently not identified as being IFP, total or item non-response may have arisen, potentially leading to bias. The exclusion of almost 10% of practices which provide veterinary care for sheep as a result of recruiting these practices for pretesting would certainly have resulted in an underestimation of the number of flocks in the study area, both affected by and at risk of developing IFP.

It was anticipated that a large percentage of participants would never have heard of IFP (or Kangaroo Gait), and it was thought that a major source of potential error would be incorrect identification of cases of IFP. In particular, painful lesions of the foot, such as those caused by foot rot or laminitis, share a number of presenting signs with IFP, such as a preference for sternal recumbency, supporting weight on the dorsal surface of the metacarpi, and proceeding with a stilted gait. For this reason, descriptions of the distinguishing features of IFP were provided in the covering letter and the introductory statement of the survey document. Care was taken not to provide descriptions of certain reported features of the condition, such as the gender or physiological state of affected sheep, that may have biased responses to questions in the survey document.

Incomplete enumeration of flocks and practices was another potential source of bias. The possibilities that not all flocks were registered with veterinary practices, or that not all flocks received visits from veterinary surgeons, were considered. However, it was thought that no other convenient or available lists existed, and that little could be done to avoid these potential problems. In any case, it was thought that such flocks would probably comprise a small percentage of the total population. The Directory of Veterinary Practices (Hall, 1997) was published two years before this study was undertaken and it is possible that some practices may have commenced veterinary care for sheep subsequent to publication. The number of such practices was thought to be low, as the general trend in the United Kingdom was believed to be the converse, with many practices ceasing to provide veterinary care for sheep, owing to the contemporary economic depression of the UK sheep industry. An over-estimation of the number of practices providing veterinary care for sheep was avoided by contacting all non-respondents by telephone and asking a member of the practice if veterinary care for sheep was still provided. Additional problems of enumeration considered were that some veterinary practices, or veterinary practitioners, may not have been identified in the Directory of Veterinary Practices as providing veterinary care for sheep, possibly through choice or error, and that some flocks may have been registered with more than one practice . Although difficult to estimate, it was again thought that these potential sources of error were likely to be small.

Comparisons between the results of this survey and the results of the June agricultural censuses of the Ministry of Agriculture, Fisheries and Food (MAFF), the Scottish Executive Rural Affairs Department (SERAD) and the Isle of Man Department of Agriculture, Fisheries and Forestry (DAFF) showed that, despite achieving a response rate of 84.7%, information was gained on only 54.3% of flocks in the study area (Table 4.5.). This may have been in part because of an overall underestimation by respondents of the number of flocks for which their practices provided veterinary care, or it may have reflected incomplete enumeration of veterinary practices and flocks in this study. A direct comparison between the two surveys must be undertaken carefully, particularly when comparing results for specific regions, as many practices provide veterinary care for flocks located outside their own regional boundaries. This may have been responsible, in part, for respondents in Cleveland estimating that their practices provide veterinary care for a greater number of flocks than those recorded within this region by the June agricultural census.

Another difficulty faced was the inability to select directly the most appropriate member of each practice to complete the questionnaire. In an attempt to minimise this problem, covering letters were addressed to the most senior members of each practice, and an instruction written to pass the questionnaire to the veterinary surgeon most involved in providing care for sheep.

Despite the perceived problem of inaccurate identification of cases of IFP, the majority of responses were consistent with reported features of the condition. Most respondents indicated that IFP was a condition of low prevalence, occurring in adult female sheep, most often with onset during lactation or late pregnancy. Those respondents who indicated that IFP had occurred in tups, lambs or wethers may have incorrectly identified other disorders of locomotion as being IFP. Alternatively, it may be that IFP can truly affect types of sheep other than adult females. If the occurrence of IFP was a random event with respect to gender, affecting less than 0.5% of animals in a flock, it is likely that females would be affected far more commonly than males, owing to the vast numerical predominance of female sheep of adult age.

Most respondents reported that onset of IFP occurred while sheep were at grass, during the months March-June. This is not surprising as these results correspond with the time of year that most adult female sheep are either approaching parturition, or are nursing lambs. These results raise the possibility, however, that onset of IFP may be associated with seasonal factors, such as meteorological, agronomic or management-related influences, as opposed to the physiological states of pregnancy or lactation. The results of this study support those of the clinical investigation of Kangaroo Gait (Chapter one) that recovery of affected animals can occur prior to weaning of the lambs. It is not possible to conclude, however, that early weaning does not lead to a more rapid recovery.

The results of this study suggest that upland and lowland flocks are more commonly affected with IFP than hill flocks. There are a number of possible explanations to account for this finding. First, it is possible that owners or managers of hill farms are less likely to report cases of IFP to their veterinary surgeons. This may be as a result of relative impoverishment, or may be due to a lower rate of contact with individual sheep. Second, environmental factors specific to hill farms, such as certain meteorological, management-related or agronomic influences, may be negatively associated with the occurrence of IFP. Third, breeds of sheep that typically graze hill pastures (such as the Scottish Blackface, the Cheviot, the Swaledale and the Welsh Mountain) may be less susceptible to IFP than typical upland or lowland breeds. Commercial cross-breeds, which are typically grazed on upland pastures, appeared to be more commonly affected than hill and lowland breeds. However, no attempt was made to determine numbers of sheep of each breed in the study area and to relate these numbers to the numbers of sheep from each breed affected by IFP, thereby determining evidence of breed susceptibility.

A further finding of this study was that the annual occurrence of IFP appeared to be increasing since it was first identified in the mid-1970s. This may reflect a true increase in the number of IFP affected flocks. Alternatively, it may reflect the inability of respondents to recall cases of IFP that occurred in the distant past, or the possibility that many respondents were not able to access information relating to cases that occurred before they were employed in their current practice.

In this chapter, no attempts to assess questionnaire reliability or validity have been described. Both are considered important measures of questionnaire quality (Vaillancourt and others, 1991). A question, asking if the respondent would be willing to participate in further studies of IFP, was included in the survey document. Chapter 5 describes a study that was subsequently undertaken, partly with the aim of measuring the validity of responses of participants from one region of the study area of this survey. In particular, it was thought that, owing in part to the contemporary economic depression of the UK sheep industry, an unknown number of cases of IFP would have occurred which were not examined by, or reported to veterinary surgeons. This may have led to an underestimation in this survey of the number of flocks affected by IFP. Further aims of the next chapter, then, were to assess the accuracy of the estimate of prevalence of affected flocks made by veterinary surgeons in this study, and to gain more detailed information relating to sheep affected by, and at risk of developing IFP.

CHAPTER 5

DEMOGRAPHIC STUDY AMONG SHEEP FLOCK OWNERS AND MANAGERS OF THE SCOTTISH BORDERS

5.1. INTRODUCTION

It was thought that, owing in part to the contemporary economic depression of the UK sheep industry, an unknown number of cases of Kangaroo Gait would have occurred which were not examined by, or reported to veterinary surgeons. This may have lead to an underestimation in the Demographic Study Among Veterinary Surgeons of Northern Britain (DSVS) (Chapter 4) of the number of flocks affected by Kangaroo Gait. In an attempt to determine the degree of underestimation, it was considered necessary to obtain a measure of the proportion of cases of Kangaroo Gait not reported to veterinary surgeons by their sheep-owning clients. The probable under-reporting of cases of Kangaroo Gait and other locomotor disorders was thought to pose a potential problem of welfare for affected sheep, which would not be apparent from any survey of veterinary surgeons. Additionally, the potential range of questions presented to veterinary surgeons in the DSVS was limited, owing to the fact that veterinary surgeons often do not have access to detailed information about individual sheep or the flocks to which they belong. It was thought that the most appropriate source of accurate and detailed information pertaining to individual cases of Kangaroo Gait, and the management of flocks from which cases of Kangaroo Gait come, would be sheep flock owners and managers. For these reasons, it was decided to undertake a survey of sheep flock owners and managers located within the study area, or part of the study area, featured in the DSVS (Section 4.2.2.).

In the DSVS no attempts to assess questionnaire reliability or validity were described. Reliability, best measured as the repeatability of responses after a brief time period, and validity, which compares questionnaire responses with independent measures of the same variable, are important indicators of questionnaire quality (Vaillancourt and others, 1991). Measures of questionnaire reliability and validity are often not undertaken or reported (Vaillancourt and others, 1991). It was thought that undertaking a further study involving sheep flock owners and managers would provide an opportunity to assess the quality of the DSVS questionnaire survey, particularly the validity of the survey, by obtaining responses from a separate group, pertaining to a number of common variables.

5.2. MATERIALS AND METHODS

5.2.1. Considerations

For reasons of confidentiality and practicality (there were no readily available lists of sheep flock owners in the study area), it was decided to recruit sheep flock owners via those veterinary surgeons who had agreed to participate in further studies of Kangaroo Gait, as indicated on the DSVS questionnaire.

It was thought that the term 'Idiopathic Forelimb Paresis' would be incomprehensible to most farmers, and a decision was taken to use the term 'Kangaroo Gait' for the purpose of this study. Additionally, if veterinary surgeons had made a diagnosis of this condition in any flocks within the study area, it is likely that they would have used the term 'Kangaroo Gait'.

5.2.2. The Study Area

The Scottish Borders was chosen as the study area for a number of reasons;

1) Veterinary surgeons from all four practices surveyed in the DSVS indicated willingness to participate in further studies of the condition termed 'Idiopathic Forelimb Paresis' (Kangaroo Gait).

2) Strict limitations in terms of financial and human resources were imposed on this study, resulting in restrictions being placed on the number of questionnaire packages and reminders that could be posted. There was therefore a requirement to select a small region from which relatively few respondents could be recruited to provide information on a large proportion of sheep from within that region.

3) It was decided to select a region within the area from which the University of Glasgow Veterinary School (UGVS) received referral cases. It was thought that a prior relationship between UGVS and practices in the study area would facilitate negotiations for further involvement of veterinary surgeons and their clients.

According to the 1999 June agricultural census of the Scottish Executive Rural Affairs Department (SERAD), the study area contained 1.48 million sheep, including 551 689

breeding ewes, 16 367 breeding rams, and 131 916 other breeding sheep greater than one year of age, all held on 992 holdings. Responses from the DSVS for the four practices in the study area indicated that they provided veterinary care for approximately 458 flocks, 11 with less than 50, 34 with 50-250, 123 with 250-500, and 280 with greater than 500 adult breeding female sheep (note figures do not add up to 458 as each response was an estimate). It was known that a number of flocks within the Scottish Borders received veterinary care from practices located in surrounding regions (the Lothians, Northumberland, Dumfriesshire, South Lanarkshire), however a decision was taken not to include these flocks in the study.

5.2.3. Recruitment of Veterinary Surgeons and Sheep Flock Owners and Managers

The respondents from the four practices in the Scottish Borders to which questionnaires had been posted in the DSVS were contacted by telephone and were asked if they were still willing to participate in a further questionnaire-based study of their sheep owning clients. All four veterinary surgeons agreed to do so. In order to maintain confidentiality, it was decided that no lists of sheep owning clients would be kept at UGVS, and only lists of clients kept at each practice would be used. Each veterinary surgeon agreed to distribute questionnaires to all of their sheep owning clients by the methods described in section 5.2.7.1.

5.2.4. Questionnaire Design and Evolution

5.2.4.1. Format

The questionnaire was designed using Microsoft Word 6.0c (Microsoft Corporation) word processing software, and was printed on both sides of five sheets of standard A4 (210 x 297 mm) paper. Questionnaires were orientated in a portrait format, and were bound with a single staple applied to the top left corner. A title 'Locomotor Disorders of Sheep' was decided, with an accompanying sub-title 'A Study Among Sheep Flock Owners of Northern Britain'.

The University of Glasgow logo was placed in a central position at the top of the front cover, above the title, above the sub-title, above the address of the Division of Farm Animal Medicine and Production (FAMP). All pages, excluding the front cover, were surrounded by a single-line border, located 1.0 cm from the edges of each page. Questions were typed in Times New Roman font. Eleven or twelve point characters were chosen for each page according to the size that allowed for the best fit of the text. Lines were separated by 1.5 line spacings.

The questionnaire was divided into four sections, titled 'Section 1: Farm Details', 'Section 2: Flock Health Details', 'Section 3: Kangaroo Gait' and 'Section 4'. The same digital photograph as that described in chapter four, section 4.2.4.1., as well as a brief description of the distinct presenting signs of Kangaroo Gait, were placed at the beginning of section three. These were provided to assist respondents in recognising cases of the condition.

5.2.4.2. Questions

The spacing and general layout of questions were the same as that described in chapter four, section 4.2.4.2.

Section 1 was aimed at obtaining demographic information for the flock, and included questions pertaining to:

1) The location, size and structure of the flock.
2) The breeds and types of sheep enterprises represented in the flock.
3) The area and topographic pasture types grazed by the flock.
4) The dates of lambing, weaning and housing.

Section 2 was aimed at obtaining information relating to the general management of the health and welfare of the flock. Specific questions sought information on the following:

1) Specific disease accreditation schemes with which the flock was registered.
2) The number of veterinary visits to the flock in 1999.
3) The use of vaccinations and antibiotics in the prevention and treatment of lameness.

4) The annual occurrence of a range of locomotor disorders.

5) The relative importance of various criteria in deciding whether or not the respondent would request veterinary attention for a diseased sheep.

Section 3 was aimed at providing specific information relating to cases of Kangaroo Gait. Questions were asked on the following:

1) The presence of cases of Kangaroo Gait, both diagnosed and undiagnosed by a veterinary surgeon, in the flock.

2) The annual occurrence of cases of Kangaroo Gait in the flock.

3) The breed, gender, physiological state, management, outcome, and time of year of onset, of cases of Kangaroo Gait in the flock.

Section 4 was placed on the back cover and included the following:

1) A large space for general comments.

2) A request for the respondent to indicate whether or not he/she would like to receive a summary of the results of the study.

The response units varied for different questions in the survey document, and included the individual sheep, the flock and the flock owner/manager. The question relating to the number of sheep of each gender/age group affected by a range of locomotor disorders, which required a large amount of information, was presented in a tabular format. Questions requiring a numerical response, or a date, such as those relating to the number of sheep in each age group or breed, and lambing, weaning and housing dates, were open-ended. Closed-ended unordered questions included those relating to membership of disease accreditation schemes, and the relative importance of various criteria in requesting veterinary attention to diseased sheep. Closed-ended ordered questions included those relating to the likelihood that the respondent would request veterinary attention to a diseased sheep, and the months of the year during which cases of Kangaroo Gait had initially occurred. In a number of questions where the list provided of possible responses was not exhaustive, a partially closed-ended format was chosen, such as the question relating to the types of sheep enterprises represented on the farm. Some questions were designed so as to require a simple yes/no response, such as

those relating to the occurrence of cases of Kangaroo Gait diagnosed and undiagnosed by veterinary surgeons.

5.2.5. The Accompanying Letter

The design and printing of the accompanying letter were identical to those described in chapter four, section 4.2.5, except that salutations were not hand-written and individually addressed to the respondent. There were four paragraphs. The first and second paragraphs explained the reason for undertaking the study. The third paragraph described how the respondent's flock had been selected, and included a guarantee of confidentiality. The concluding paragraph reiterated the importance of the study and invited prospective respondents to contact the author should they have any queries regarding the questionnaire. Unlike the questionnaire, the accompanying letter was not extensively pretested. A small number of colleagues at the Division of FAMP were shown the final draught (Appendix 11), and upon general recommendation no further changes were incorporated.

5.2.6. Pretesting the Questionnaire

As described in chapter four, section 4.2.6.1., a number of colleagues (six) from the Division of FAMP, and the Comparative Epidemiology and Informatics research group (CEI) at UGVS were recruited for pretesting the questionnaire, resulting in several changes being incorporated into the document.

The title was changed to include sheep flock managers. Contact details, which were located at the beginning of Section 1, were removed from the document except the postcode. The postcode was considered necessary as it was possibly to be used for later geocoding of data for graphical display. In Section 2, an additional question, relating to whether or not the respondent had a written flock health plan, was included. The instructions for the question relating to the number of sheep of each gender/age group affected by a range of locomotor disorders, considered difficult by many, were simplified, and lines were placed in each box in the table to facilitate correlation between responses and the types of sheep to which they referred. Additionally, many of

the terms used in the table were considered too technical, and these were modified to be more understandable to the subjects of the study. Several changes were also made to the ordering of questions, and the syntax of the text.

The improved draught was submitted to four stockpersons and farm managers, employees of UGVS or associated farms, for the purpose of further pretesting. Each subject was given a copy of the questionnaire for completion, and was subsequently interviewed in order to gain information on the existence of difficult words and ambiguous or inappropriate questions, as well as the length of time taken to complete the document, and any further suggestions for its improvement. A number of changes were made following this second stage of pretesting. Question one (the postcode) was thought to be out of place and was moved to the end of section one, where it was thought to be less conspicuous. *'This season's lambs'* in question two was further defined by adding *'winter 1999/2000'*. In question five, an additional qualification was added, stating that the question only pertained to the largest of the respondent's flocks, as it was anticipated that many respondents would own multiple or divided flocks with different lambing dates. In question 11, the term *'Enzootic Abortion of Ewes'* was added, as it was thought that some respondents may not be familiar with the acronym E.A.E. A final draught of the questionnaire can be found in Appendix 10.

5.2.7. Mailing

5.2.7.1. The First Mailing

Each mailing package contained the questionnaire, the accompanying letter, and a white return envelope (size 110 x 220 mm), stamped with a first class commemorative stamp. The three components were folded as described in section 4.2.7.1. Questionnaire packages were mailed to each practice, and distributed to sheep owning clients, using either of the following methods, as agreed with the veterinary surgeons:

1) White envelopes (size 110 x 220 mm) containing questionnaire packages were sent to the practice and were hand-addressed by a member of staff at the practice.

2) Questionnaire packages were sent to each practice, and were be placed in the practices' own envelopes, accompanying monthly invoices or newsletters, addressed to sheep owning clients for these other purposes.

No marks were placed on questionnaires for identification purposes. Each veterinary surgeon was asked to estimate the number of questionnaires required for mailing to all of their sheep owning clients. The combined total of estimates of numbers of questionnaires required by the four veterinary practices was 521. This number plus approximately 20 extra questionnaires were posted to the four practices in early February, 2000. The four veterinary surgeons were asked to return all unused questionnaires to facilitate the calculation of the sample size. A total of 438 sheep owners or managers were posted copies of the questionnaire package between early February and early March 2000. As completed questionnaires were returned to UGVS, the date of receipt was recorded on the front cover.

5.2.7.2. Subsequent Mailings and Follow-Ups

Two of the four veterinary surgeons agreed to distribute reminders to their sheep-owning clients. A postcard reminder (Appendix 12), designed with identical software, incorporating a similar format and containing similar information to that described in chapter four, section 4.2.7.2 was printed on yellow 90 GM^2 paper. One variation in the design was that salutations were not individually hand-written to each respondent.

All 256 clients from these two practices were sent a postcard reminder. For one of the veterinary practices, postcards were placed in plain white envelopes (110 x 220 mm), with a regular first class stamp affixed, and were posted to the practice on 6 March, 2000, in a single container, where individual names and addresses were hand-written on envelopes prior to posting. For the other practice, postcards were posted to the practice on 6 March, 2000, in a single container, where they were placed in envelopes accompanying monthly invoices and newsletters.

It was decided not to undertake any further follow-ups. This was because the large amount of work required for the distribution of reminders, undertaken on a voluntary basis by staff at the participating practices, was considered prohibitive.

5.2.8. Database Design and Analysis

A database table, using a similar design and incorporating the same principles as those outlined in chapter four, section 4.2.8., was created, and identical software was used for the analysis and transformation of data, including chi square analyses. Once again, chi-square tests with P-values less than 0.05 were considered to demonstrate significant differences.

5.3. RESULTS

5.3.1. The Response

Questionnaires were received from 137 respondents. One respondent indicated they no longer owned sheep and two questionnaires were deemed unusable, leaving 134 useable questionnaires received from 437 sheep flock owners or managers. The useable response rate was, therefore:

$$134/437 \times 100 = 30.7\%$$

According to the 1999 June agricultural censuses of SERAD, the Scottish Borders contained 992 holdings. Therefore, data were obtained from approximately 13.5% of flocks in this region.

Since questionnaires were posted over a period of one month, and because there were no marks of identification indicating which practice distributed each questionnaire, no pattern of response could be determined.

5.3.2. Survey Data

5.3.2.1. Farm Details

One hundred and thirty-three respondents answered question one, pertaining to numbers of each type of sheep in the flock, with one respondent only providing details on numbers of adult female sheep. The descriptive statistics relating to this question are summarised in Table 5.1. There were 2 498 tups, 77 983 adult ewes, 23 792 gimmers, 33 099 lambs and 7 562 other sheep. Other sheep included 4 392 ewe hoggs, 1 341 hoggs (gender not specified), 368 tup hoggs, 305 wethers, 80 cast ewes, 30 dinmonts, 21 feeders and 12 teaser rams. Five flocks had less than 50 breeding female sheep, 20 had 50-250, 23 had 250-500 and 87 had >500 breeding female sheep (53 had 500-1000 and 34 had >1 000). The most numerous breeds included the Greyface Mule and the Scottish Blackface with greater than 20 000 breeding females each, followed by the Mule (Scottish or English) and the Cheviot with approximately 17 000 breeding females each (Table 5.2.). In total there were approximately 45 212 commercial cross, 40 422 hill breed, 6 605 Texel and Texel cross, 3 874 Suffolk and Suffolk cross, 2 862 other native lowland breed and cross and 394 other European lowland breed and cross breeding female sheep.

One hundred and thirty-three respondents answered question three, pertaining to types of sheep-related enterprises within the flock (Figure 5.1.). Most indicated that they produced commercial fat lambs (89.5%). Significant numbers of respondents also indicated that they produced commercial breeding stock (39.8%) and pedigree breeding stock (30.1%). A small number (7.5%) of respondents indicated that their flocks were dedicated to other sheep-related enterprises, all of whom indicated that they produced store lambs. One hundred and twenty-six respondents answered question four, pertaining to numbers of hectares grazed by sheep in each topographic category. The study area was comprised mostly of hill and upland pasture, with a small amount of lowland pasture (Table 5.3.). The mean number of hectares per farm of each type of pasture were 36.6, 148.0 and 168.3 (lowland, upland and hill respectively). Figure 5.2. shows the percentage of flocks that are predominantly managed under each production system. Flocks with greater than 75% of their area belonging to a particular topographic

type were identified as being predominantly managed under the relevant grazing system. Flocks where no topographic type comprises greater than 75% of the area were categorised as mixed lowland/upland, lowland/hill or upland/hill.

All respondents answered questions five and six, pertaining to the commencement date and length of the lambing period. Lambing commenced on farms between 26 December, 1998 and 5 May, 1999, and the lambing period ranged from 2-8 weeks. Twenty-one flocks were categorised as early lambing flocks (lambing commenced on or before 7 March, 1999), 56 as intermediate lambing flocks (lambing commenced between 7 March and 1 April, 1999) and 56 as late lambing flocks (lambing commenced on or after 1 April, 1999). One hundred and twenty-six respondents answered question seven. Weaning dates ranged from 26 February to 15 October, 1999. Responses to question seven indicated that 74 flocks were housed 24 hours per day. Housing commenced between 15 November, 1998 and 12 April, 1999. Turnout occurred between 1 February, 1999 and 15 May, 1999. Responses to question eight indicated that 18 flocks were partly housed, where sheep were allowed to graze at pasture for at least part of the day. Part housing commenced between 15 December, 1998 and 6 April, 1999. Sheep were turned out 24 hours per day between 28 February 1999, and 21 May, 1999. In Figure 5.3., each week between the beginning of lambing and the end of weaning is given a number, with week two starting 1 January, 1999. The number of respondents indicating weeks during which lambing commenced and ended, and during which lambs were weaned, is plotted on a histogram. Similarly, the number of respondents indicating weeks during which housing of sheep commenced and ended is plotted on a histogram in Figure 5.4. In this figure, week eight starts 1 January, 1999.

Table 5.1. Summary of descriptive statistics relating to numbers of each type of sheep in flocks owned or managed by respondents.

Descriptive Stat.	Tups	Ewes	Gimmers	Lambs	Other
Mean	18.9	586.3	180.2	250.8	57.3
Standard Error	1.3	36.9	12.2	40.6	11.4
Median	16.5	530	154	52.5	0
Mode	20	600	200	0	0
Standard Deviation	14.9	425.6	140.6	466.6	130.7
Range	81	2 335	856	2 000	1 000
Minimum	0	10	0	0	0
Maximum	81	2345	856	2000	1000
Sum	2 498	77 983	23 792	33 099	7 562
Count	132	133	132	132	132

Table 5.2. Total number of sheep belonging to each breed and cross breed.

Breed	Total Number of Sheep
Greyface Mule	22 141
Scottish Blackface	21 615
Mule (Scottish and English)	17 254
Cheviot (North and South Country)	17 029
Halfbred	5 695
Texel cross	5 364
Suffolk cross	2 452
Lleyn and Lleyn cross	2 045
Suffolk	1 422
Texel	1 214
Swaledale	848
Hill Breed cross	795
French Breed cross*	394
Meatlinc and Meatlinc cross	340
Leicester (Border and Blue-Faced)	311
Shetland and Shetland cross	130
Poll Dorset and Poll Dorset cross	125
Masham	120
Oxford Down	41
Jacob	5

* Includes Rouge de L'Ouest, Bleu de Maine and Charollais

Figure 5.1. Sheep production enterprises represented by flocks owned or managed by respondents.

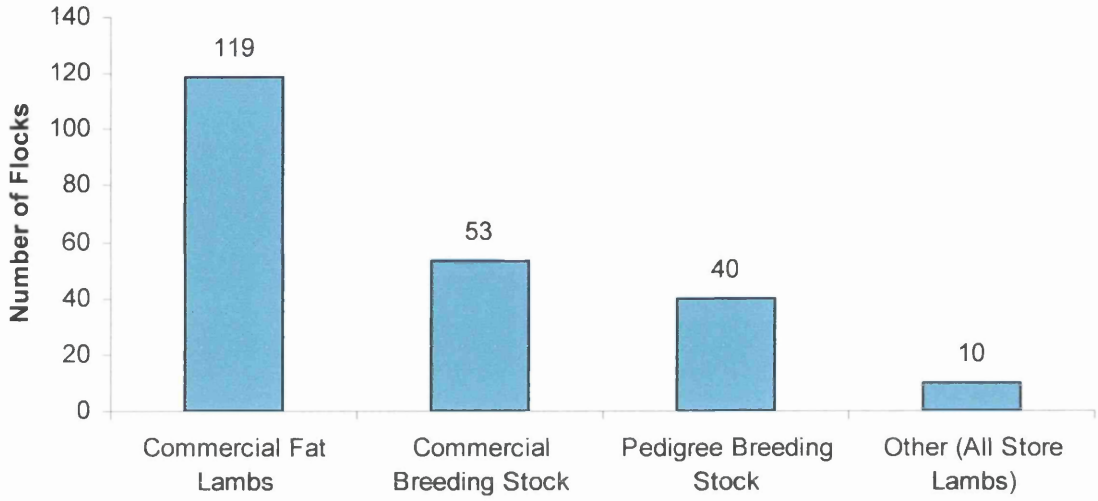


Table 5.3. Summary of descriptive statistics relating to numbers of hectares of each pasture type (topographic type) dedicated to sheep production on farms owned or managed by respondents.

Descriptive Statistic	Lowland	Upland	Hill
Mean	32.6	148.0	168.3
Standard Error	11	25.2	27
Median	0	64	0
Mode	0	0	0
Standard Deviation	124.0	283.0	302.8
Range	1 200	2 400	1 261
Minimum	0	0	0
Maximum	1 200	2 400	1 261
Sum	4 103	18 644	21 205
Count	126	126	126

Figure 5.2. Percentages of flocks predominantly managed under each production system (topographic type).

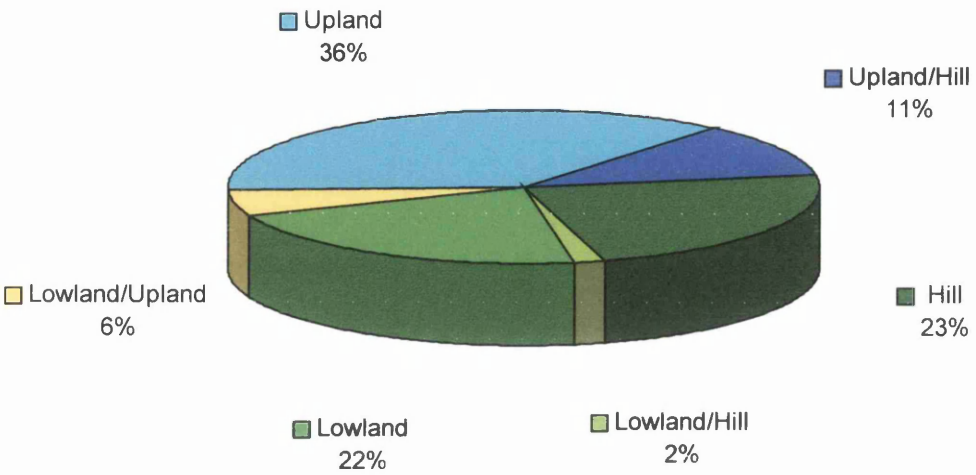


Figure 5.3. Numbers of respondents indicating weeks during which lambing commenced and ended, and during which lambs were weaned during 1998/1999 (Week two starting January 1st, 1999).

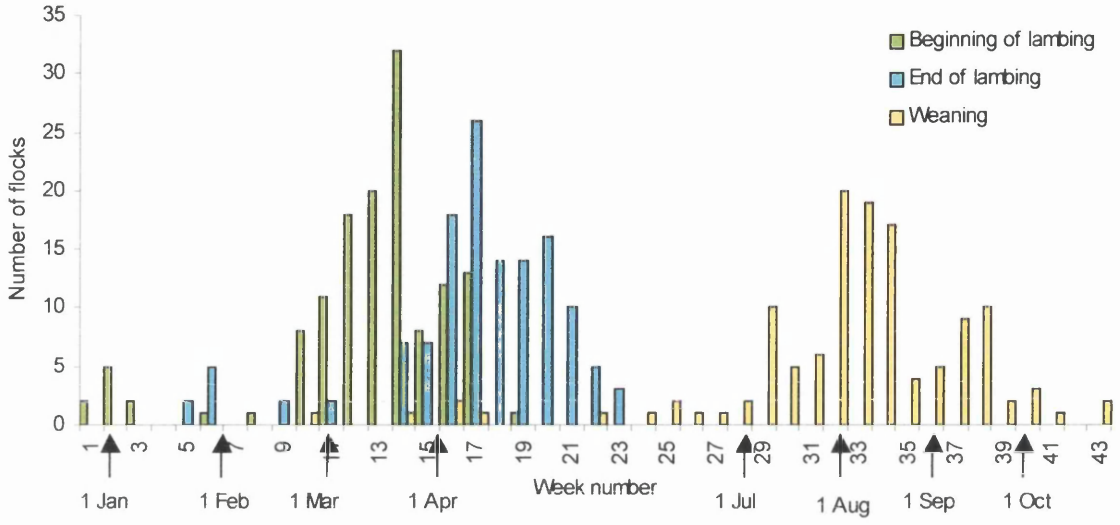
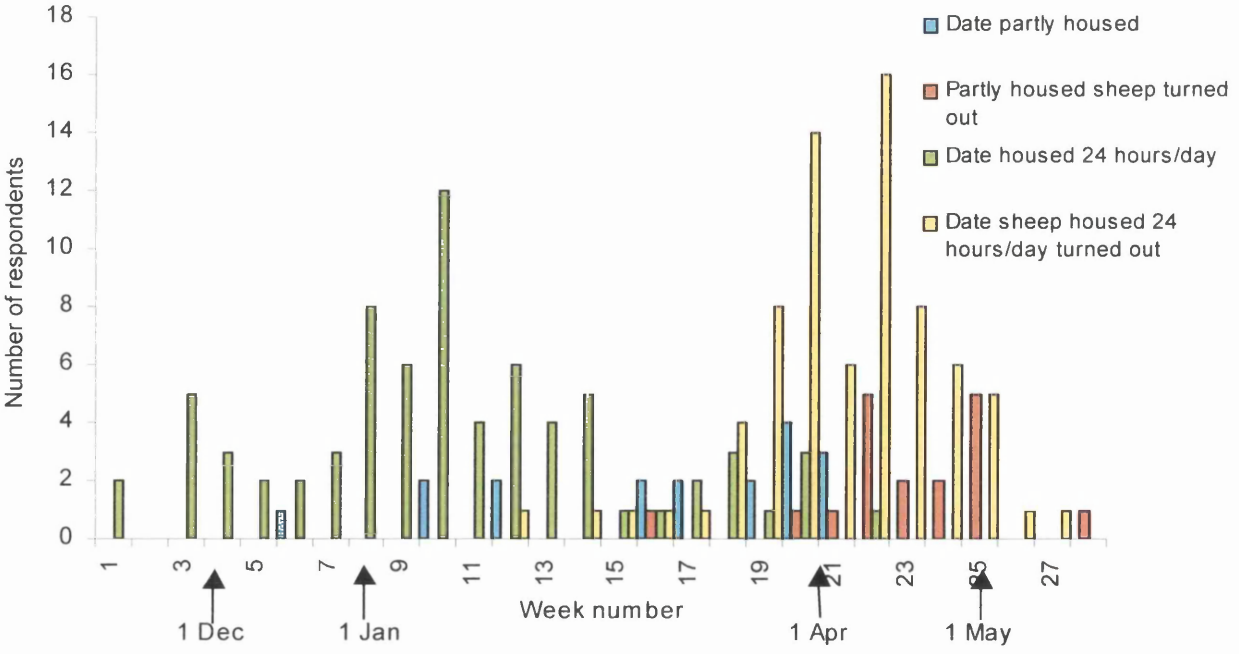


Figure 5.4. Numbers of respondents indicating weeks during which housing of sheep commenced and ended during 1998/1999, including dates partly housed and dates housed 24 hours per day (Week eight starting January 1st, 1999).



5.3.2.2. Flock Health Details

A minority of flocks belonged to disease accreditation and monitoring schemes, with the greatest number belonging to enzootic abortion (EAE) accreditation schemes or Scrapie monitoring schemes. Slightly fewer flocks belonged to Maedi-Visna (MV) accreditation schemes and only one flock was a member of a MV monitoring scheme (Table 5.4.). Of the 127 respondents who answered question 12, 37 (29.1%) indicated they had a written flock health plan containing details on prevention and treatment of lameness. One hundred and twenty-seven respondents answered question 13, pertaining to the number of veterinary visits received by each flock in 1999. A summary of the descriptive statistics for this question is provided in Table 5.5., indicating that there were a total of 231 veterinary visits made to respondents' flocks, with a mean of 1.8 visits per flock. In answer to question 14, the majority of respondents (70%) indicated that their response to question 13 represented no change, when compared to the number of veterinary visits received by each flock in the previous five years. A significant proportion, however, (27%) indicated that their response represented a decrease, and only three respondents (2.4%) indicated that their response to question 13 represented an increase in the number of veterinary visits (Table 5.6.). Of the 116 respondents who answered question 15, three (2.6%) indicated they were more likely to request veterinary attention for a diseased sheep in 1999 compared to the previous five years, 32 (27.6%) indicated they were less likely and 81 (69.8%) indicated there was no change in likelihood.

Of the 133 respondents who answered questions 16 and 17, six (4.5%) indicated that they vaccinated for foot rot and 120 (90.2%) indicated that they kept antibiotic preparations on the farm for the treatment of lameness. Figure 5.4. shows the number of respondents who kept different types of antibiotics for the treatment of conditions causing lameness. The most commonly kept antibiotics were oxytetracyclines (various preparations), followed by penicillins, combined penicillin-streptomycins, and other antibiotic preparations. Other antibiotic preparations included ointments and pastes.

One hundred and seventeen respondents answered question 18, pertaining to the number of cases of each category of locomotor disorder affecting sheep, for which veterinary

attention was, and was not, sought. Overall, interdigital lesions were the commonest cause of locomotor disorders, followed by disorders of the hoof, painful disorders of the joints, painful lesions of the skin and udder, trauma, gait abnormalities of all four limbs, weakness of both hind limbs, weakness of both fore limbs and abnormal conformation (Figure 5.6.). Only 2.3% of all sheep affected with locomotor disorders and 6.7% of all sheep affected with weakness of the forelimbs, received veterinary attention (Table 5.7.). Summary tables of descriptive statistics for each response to this question are provided in Appendix 13.

Figures 5.7-5.13. show responses to each option in question 19, where respondents were asked to rank seven criteria in decreasing order of importance when considering whether or not they would request veterinary attention for a diseased sheep. Option one (Figure 5.7.), relating to the degree of pain and discomfort experienced by the sheep, was ranked as the most important criterion by 44.8% of respondents, and as one of the three most important by 76.8%. Option one was, therefore, the criterion most consistently considered to be the most important. Option five (Figure 5.11.), relating to concern that other sheep will become affected, was ranked as one of the three most important criteria by 68.0% of respondents and as one of the three least important by 24.0%, and was, on this basis, the second most highly ranked criterion. Option three (Figure 5.9.), relating to the respondent's level of confidence that he/she could diagnose and treat the condition without veterinary assistance, was ranked as one of the three most important criteria by 63.2% of respondents and as one of the three least important by 17.6% of respondents, and was, on this basis, the third most highly ranked criterion. Option two (Figure 5.8.), relating to financial considerations, was ranked as one of the three most important criteria by 47.2% of respondents, and one of the three least important by 32.8%. Option six (Figure 5.12.), relating to likelihood that the vet would find a cure or increase the productivity of the sheep, was ranked as one of the three most important criteria by 36.0% of respondents and as one of the three least important by 43.0%. Option seven (Figure 5.13.), relating to what other farmers or members of the public may think should they see a diseased sheep, was ranked as one of the three most important criteria by 29.6% of respondents and as one of the three least important by 63.2%, making it the second lowest ranked criterion on this basis. Option four (Figure 5.10.), relating to cost in labour and time should treatment be necessary, was ranked one of the three most

important criteria by 12.8% of respondents, and as one of the three least important by 76.8%, and was therefore the most lowly ranked criterion.

Table 5.4. Numbers of flocks accredited or monitored by various national schemes.

Scheme	Number of Flocks
EAE accredited	16
MV accredited	15
MV monitored	1
Scrapie monitored	16

Table 5.5. Summary of descriptive statistics relating to numbers of veterinary visits received by flocks, owned or managed by respondents, in 1999.

Descriptive Statistic	Veterinary Visits per Flock
Mean	1.8
Standard error	0.3
Median	1
Mode	0
Standard deviation	2.8
Range	20
Minimum	0
Maximum	20
Sum	231
Count	127

Table 5.6. Response to question 14: Does the number of veterinary visits to the flock in 1999 represent an increase, a decrease or no significant change when compared to the number of annual visits during the previous five years?

Response	Number of Respondents
Increase	3
Decrease	32
No significant change	81

Figure 5.5. Numbers of respondents who kept different types of antibiotics for the treatment of lameness.

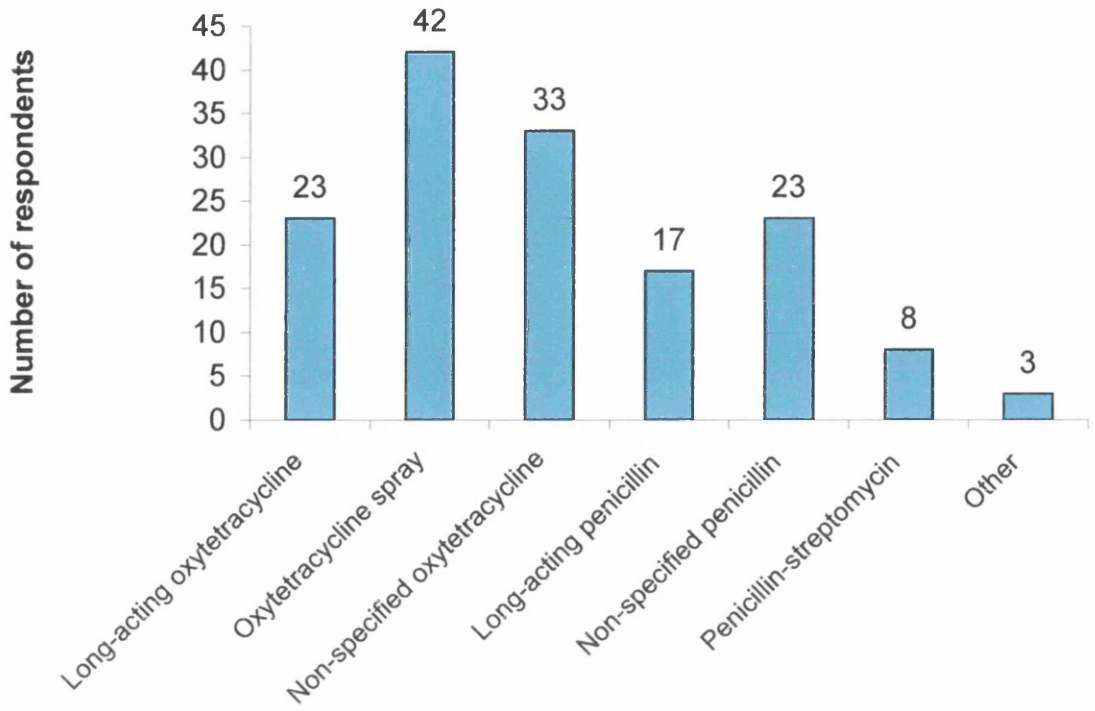


Figure 5.6. Percentages of the total number of cases of locomotor disorders in each category.

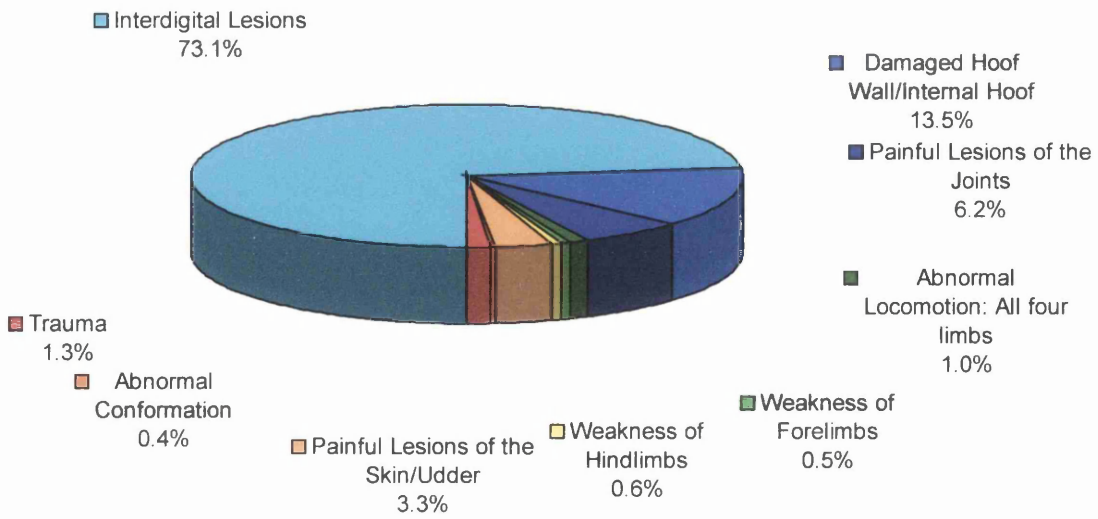


Table 5.7. Numbers of cases of locomotor disorders, and percentages of cases where veterinary attention was sought, in each type of sheep and in each category of disorder.

Category	Type of sheep	Number of cases where vet. attention was sought	Number of cases where no vet. attention was sought	Percentage of the total number of cases where vet. attention was sought
Interdigital lesions	Tups	2	593	0.3
	Ewes	150	6 414	2.3
	Lambs	30	3 361	0.9
Damaged hoof wall or internal hoof structures	Tups	2	175	1.1
	Ewes	20	1 209	1.6
	Lambs	0	541	0.0
Painful lesions of the joints	Tups	2	33	5.7
	Ewes	0	104	0.0
	Lambs	83	665	11.1
Abnormal gait: all four limbs	Tups	2	6	25.0
	Ewes	1	78	1.3
	Lambs	4	52	7.1
Weakness of both forelimbs	Tups	0	4	0.0
	Ewes	5	48	10.2
	Lambs	0	18	0.0
Weakness of both hindlimbs	Tups	1	1	50.0
	Ewes	5	21	19.2
	Lambs	1	61	1.6
Painful lesions of the skin or udder	Tups	0	16	0.0
	Ewes	5	434	1.1
	Lambs	0	18	0.0
Abnormal conformation	Tups	0	0	N/A
	Ewes	3	15	16.7
	Lambs	0	40	0.0
Trauma	Tups	0	12	0.0
	Ewes	0	63	0.0
	Lambs	4	115	3.4
All locomotor disorders	Tups	9	840	1.1
	Ewes	189	8 386	2.3
	Lambs	122	4 871	2.5
	All Sheep	**320**	**14 097**	**2.3**

Figure 5.7. Degree of pain experienced by the sheep.

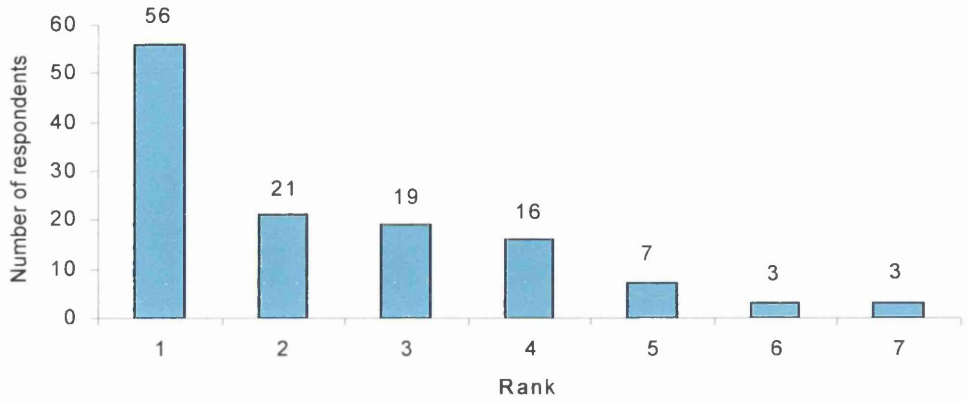


Figure 5.8. Financial considerations.

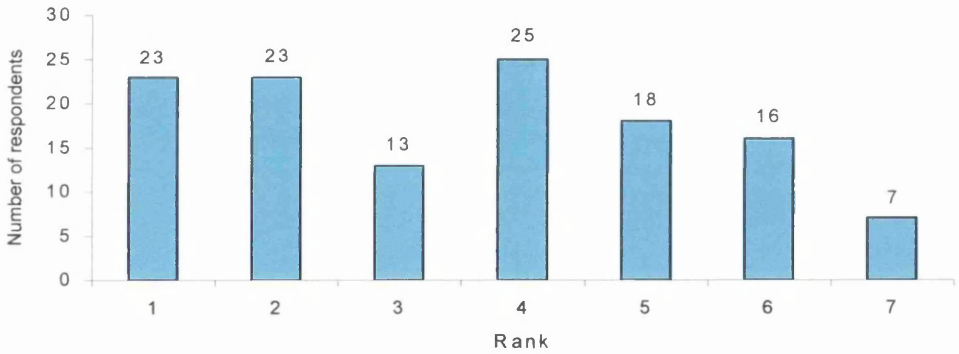


Figure 5.9. Level of confidence that the respondent can make a diagnosis

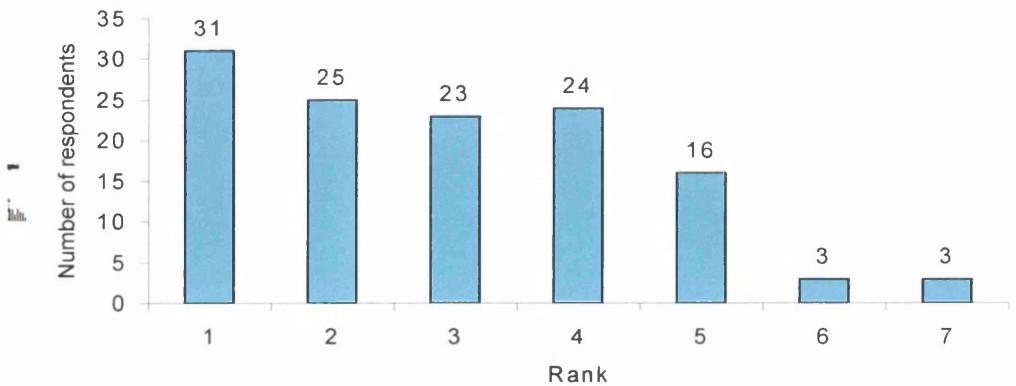


Figure 5.10. Cost in labour and time should treatment be necessary.

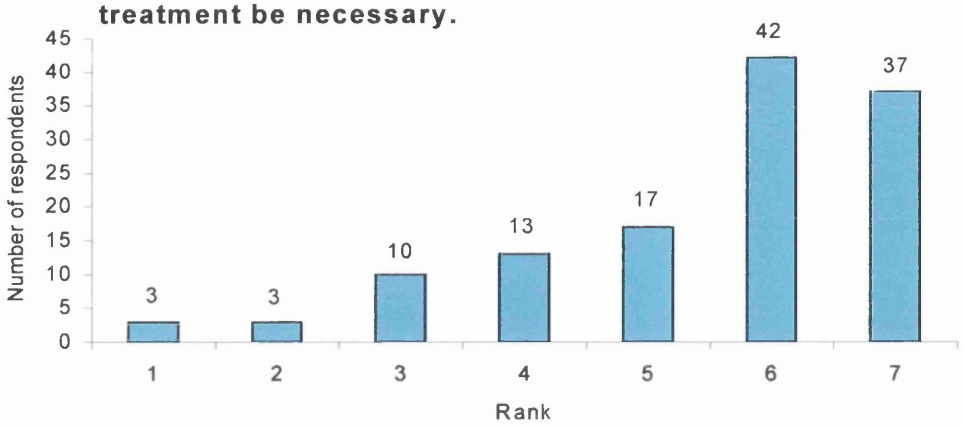


Figure 5.11. Concern that other sheep will become affected.

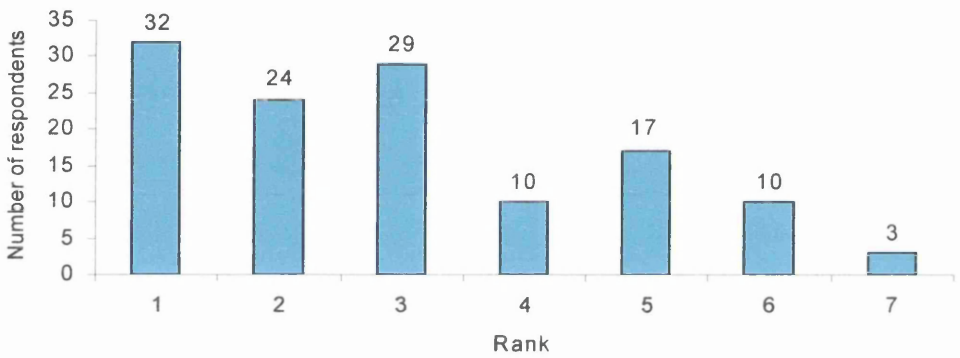


Figure 5.12. Liklehood that the vet will find a cure/increase productivity of the sheep.

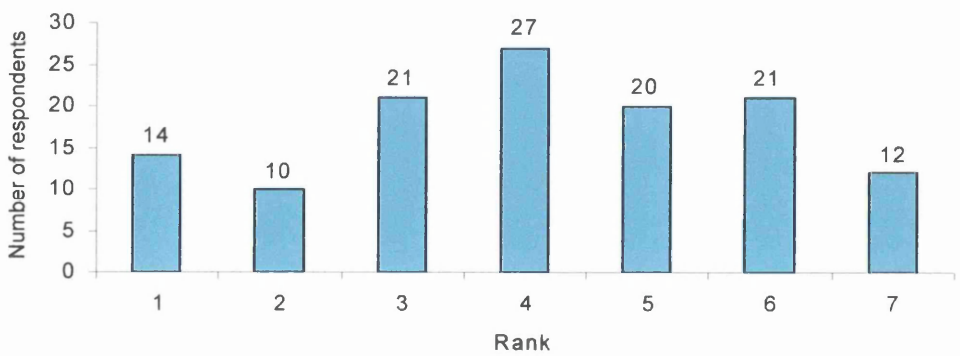
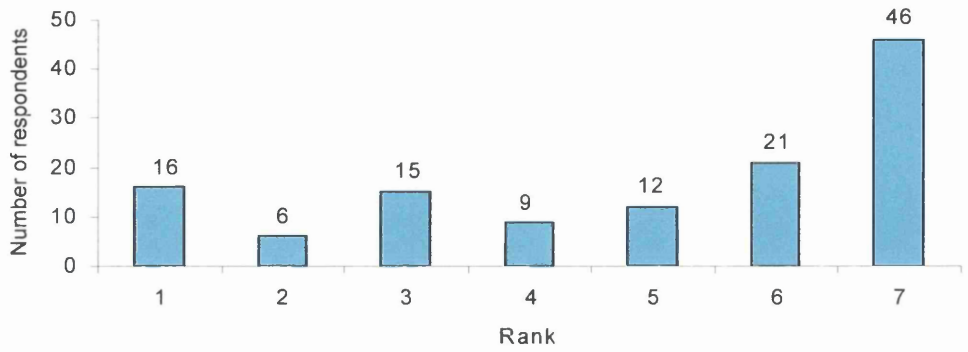


Figure 5.13. What other farmers/members of the public may think.



5.3.2.3. Kangaroo Gait

One hundred and thirty-three respondents answered question 20, indicating that 14 (10.5%) had had one or more cases of Kangaroo Gait in their flock, diagnosed by a veterinary surgeon (Table 5.8.). Twelve of these respondents also indicated that they had had one or more sheep in their flock demonstrating signs of Kangaroo Gait for which no veterinary attention was sought. The thirteen respondents who answered question 21 indicated that the earliest case that they could recall diagnosing had occurred in 1984, and in the majority of flocks, the first case had been diagnosed after 1995 (53.8%) (Table 5.9.). Thirty respondents (22.6%) indicated that sheep had demonstrated signs of Kangaroo Gait in their flock for which they did not seek veterinary attention (question 22) (Table 5.10.). Therefore, a total of 32 respondents (24.1%) indicated that one or more sheep in their flocks had demonstrated signs of Kangaroo Gait, either for which veterinary attention was or was not sought. Responses were gained from 90 respondents for question 23, pertaining to the number of cases of a gait abnormality resembling Kangaroo Gait that would have to occur in adult female sheep before they would seek veterinary attention, the summary statistics for which are provided in Table 5.11. On average, 4.2 cases of Kangaroo Gait would have to occur in flocks before veterinary attention was sought, but responses to this question varied considerably.

Twenty-three of the 27 respondents (85.2%) who answered question 24 indicated that one or more sheep affected with Kangaroo Gait had belonged to commercial cross

breeds. The greatest number of respondents indicated that sheep belonging to the Mule breeds (Scottish or English) had been affected, followed by the Greyface Mule (Table 5.12.). Only one respondent indicated that sheep from a hill breed had been affected (Scottish Blackface). Responses to question 25 (Figure 5.14.) indicated that there had been a small increase in the number of cases of Kangaroo Gait in the study area during the years 1997-1999, from 26 cases to 35 cases. A lower average annual occurrence was apparent prior to 1997 (there were 6.1 cases per year in the years 1990-1996). In the years 1997-1999, in which one or more cases of Kangaroo Gait occurred, the average annual occurrence of the condition among adult females was between 0.5-1.0% in three flocks (12.5%), 0.2-0.5% in ten flocks (41.7%) and less than 0.2% in 11 flocks (45.8%). Thirty respondents answered question 26, which related to whether or not sheep had developed Kangaroo Gait in two or more years. Only two respondents (6.7%) stated that sheep had developed Kangaroo Gait in two or more years (Table 5.13.), although a large percentage of respondents indicated that they were unsure. Responses to question 27 indicated that in the majority of affected flocks, onset of cases of Kangaroo Gait occurred in the months March-June, with a small, separate peak in October (Figure 5.15.). In question 28, most respondents indicated that onset of Kangaroo Gait had occurred at grass. Only three respondents indicated that onset had occurred in sheep housed 24 hours per day, and one respondent indicated that onset had occurred in sheep kept at grass for only part of the day (Table 5.14.).

Of the thirty respondents who responded to question 29, almost all (96.7%) indicated that Kangaroo Gait had occurred in adult female sheep, including ewes and gimmers. A small number indicated that cases of Kangaroo Gait had occurred in other types of sheep, including tups (6.7%) and lambs (3.3%) (Figure 5.16.). Thirty respondents answered question 31 (Figure 5.17.). Twenty-four respondents (80.0%) indicated that onset of Kangaroo Gait had occurred in adult female sheep during lactation, seven (23.3%) indicated that onset had occurred during pregnancy, and only two (6.7%) indicated that onset had occurred between weaning and tupping. All 24 respondents who answered question 32 indicated that adult females affected with Kangaroo Gait either suckled single lambs or twins, with most respondents indicating that twins were suckled (Figure 5.18.). In flocks where adult female sheep had recovered from Kangaroo Gait, ten respondents indicated recovery had occurred while affected sheep

were nursing lambs, and 18 indicated that recovery had occurred after weaning (Figure 5.19.). In flocks in which sheep had not recovered, four respondents indicated that affected sheep had been given euthanasia, and seven respondents indicated that death had occurred due to some other cause. Only 14 respondents answered question 33, relating to flocks in which Kangaroo Gait had occurred in more than one animal in any year (Figure 5.20.). According to most respondents, animals were affected within one month of each other, although a number of respondents indicated that onset had occurred in more than one sheep within seven days or over a period greater than one month.

Thirty-one respondents gave their opinion regarding the economic importance of Kangaroo Gait in their flocks (Figure 5.21.). Kangaroo Gait was considered not to be at all important by 32.3% of respondents and to be of little importance by 48.4% of respondents. Only five respondents (16.1%) considered Kangaroo Gait to be of moderate importance and one respondent (3.2%) considered Kangaroo Gait to be very important.

Table 5.8. Responses to question 20: Have any cases of Kangaroo Gait been diagnosed in the respondent's flock following examination by a veterinary surgeon?

Response	Number of Respondents
No	119
Yes	14

Table 5.9. Responses to question 21: The year in which the first case of kangaroo was diagnosed in each flock.

Year	Number of Respondents
1999	2
1997	2
1996	3
1995	1
1994	1
1990	1
1989	1
1985	1
1984	1

Table 5.10. Responses to question 22: Have any sheep in the respondents' flock demonstrated signs of Kangaroo Gait for which no veterinary attention was sought?

Response	Number of Respondents
No	103
Yes	30

Table 5.11. Summary of the descriptive statistics relating to the number of cases of Kangaroo Gait that would have to occur in the respondents' flocks before they would request veterinary attention.

Descriptive Statistic	Result
Mean	4.2
Standard Error	0.8
Median	3
Mode	2
Standard Deviation	7.6
Minimum	1
Maximum	70
Sum	377
Count	90

Table 5.12. Numbers of respondents who indicated that Kangaroo Gait had occurred in one or more sheep belonging to each breed.

Breed	Number of Respondents
Mule (Scottish or English)	10
Greyface mule	8
Halfbred	6
Suffolk X	2
Suffolk	1
Texel X	1
Poll Dorset X	1
Bleu de Maine X	1
Scottish Blackface	1

Figure 5.14. Numbers of sheep affected during each time period in flocks owned or managed by respondents.

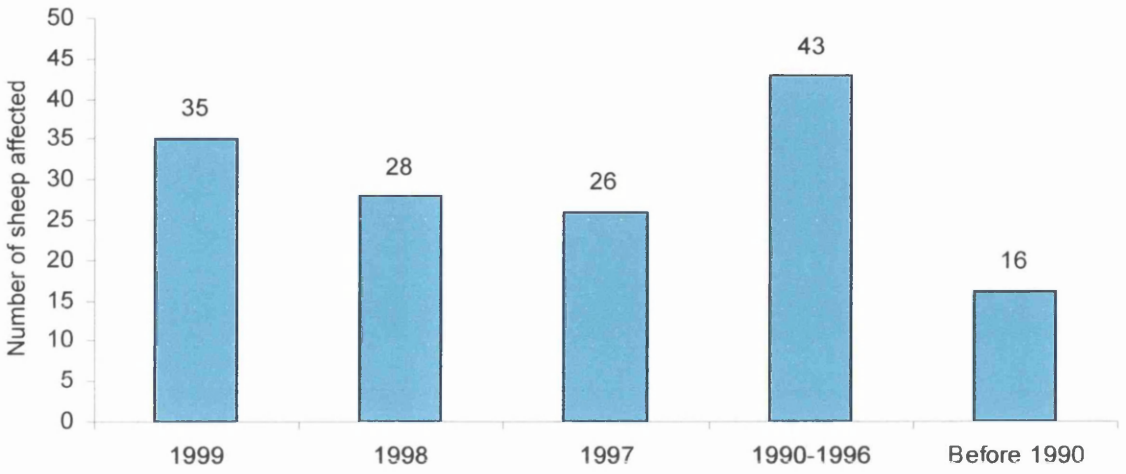


Table 5.13. Responses to question 26: Have any sheep developed Kangaroo Gait in two or more years?

Response	Number of Respondents
No	17
Yes	2
Unsure	10

Table 5.14. Responses to question 28: Have any sheep developed Kangaroo Gait while kept under each of the following housing systems?

Response	Number of Respondents
At grass	28
Housed 24 hours per day	3
Housed temporarily (at grass during part of the day)	1

Figure 5.15. Numbers of respondents who indicated that cases of Kangaroo Gait had initially occurred during each of the months of the year.

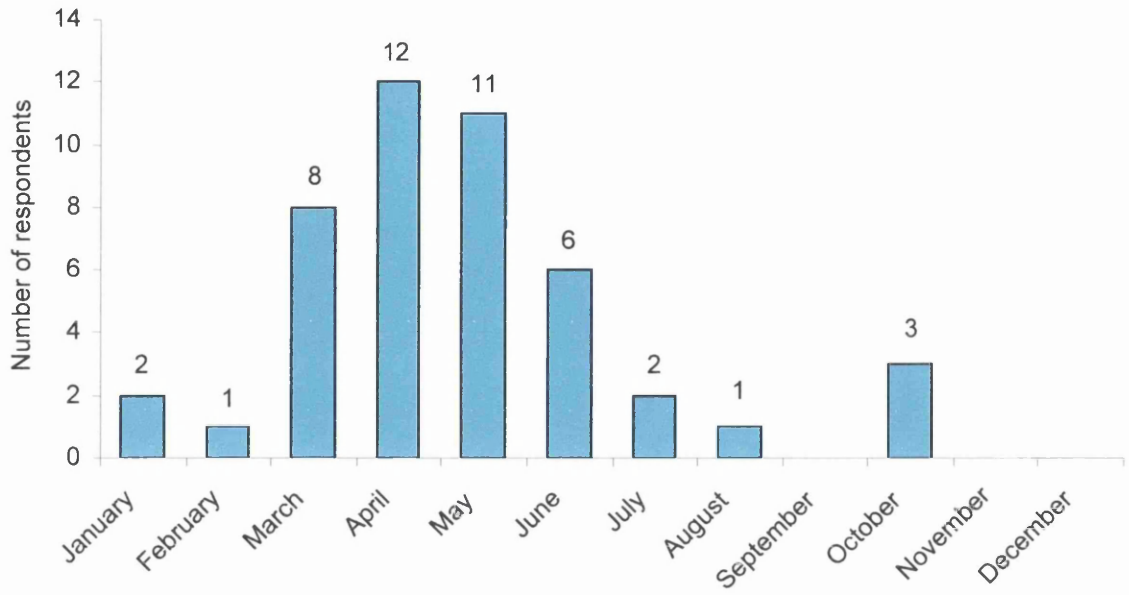


Figure 5.16. Numbers of respondents who indicated that one or more cases of Kangaroo Gait had occurred in each type of sheep.

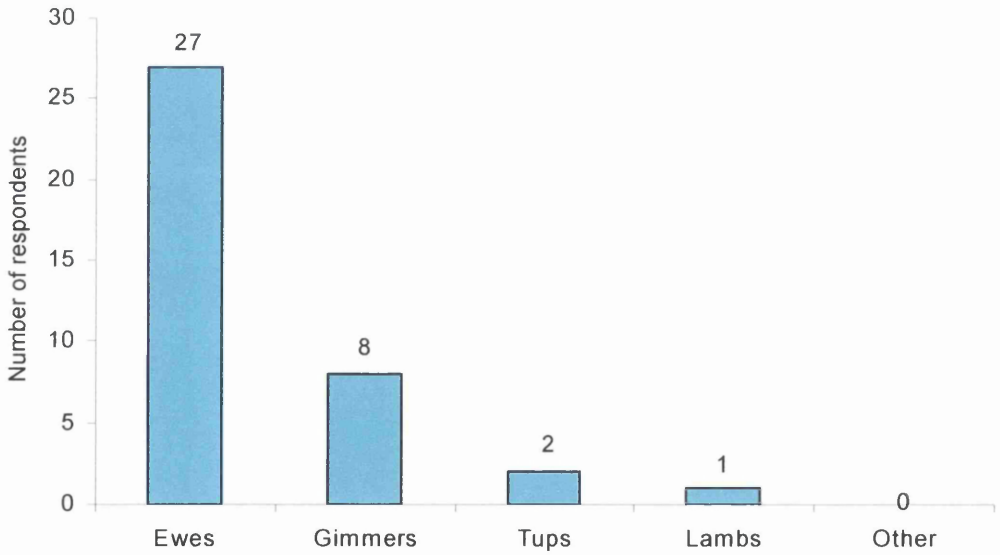


Figure 5.17. Numbers of respondents who indicated that Kangaroo Gait had occurred in one or more adult female sheep during each of the following stages.

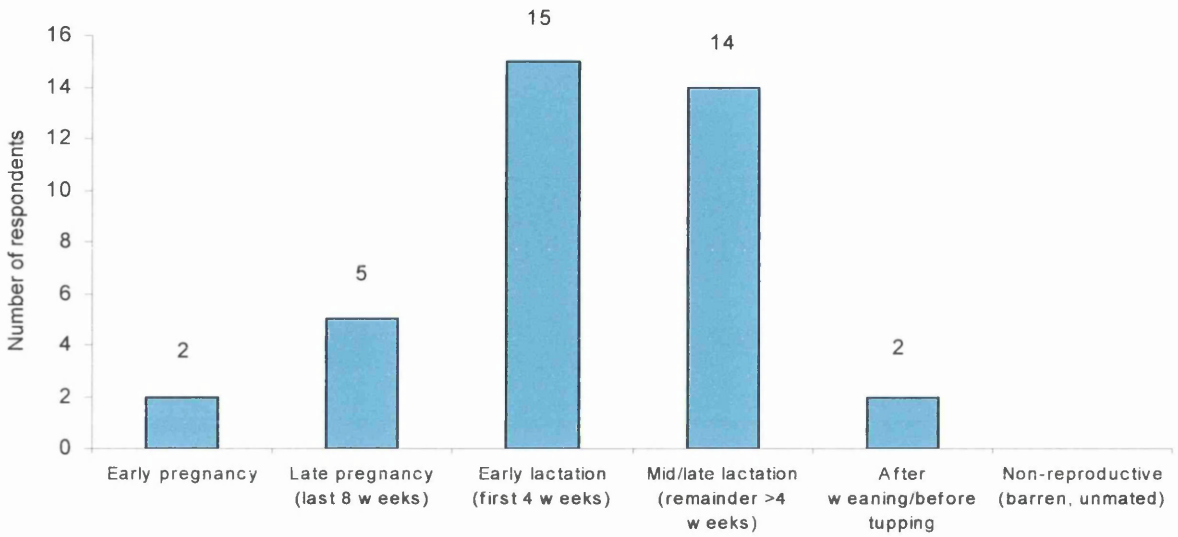


Figure 5.18. Numbers of respondents who indicated that Kangaroo Gait had occurred in one or more adult female sheep suckling a particular number of lambs.

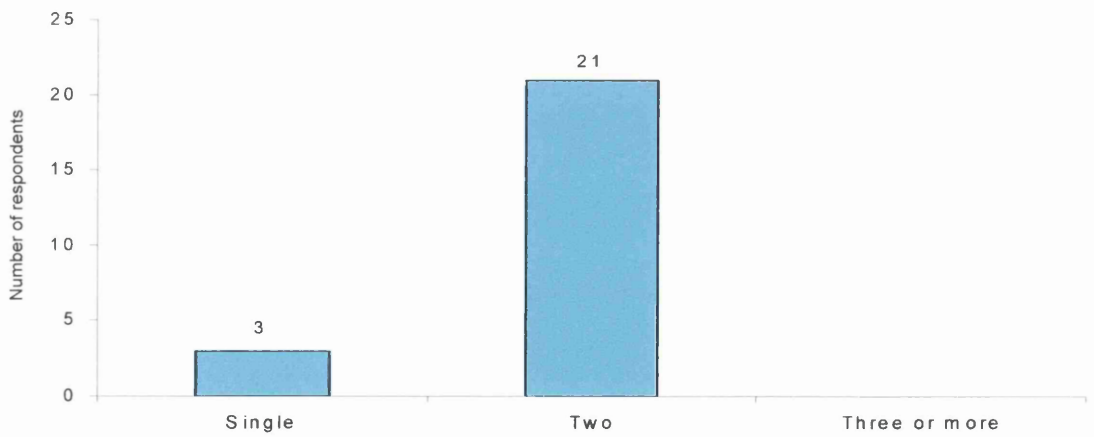


Figure 5.19. Numbers of respondents who indicated which outcomes had resulted following onset of Kangaroo Gait in one or more adult female sheep.

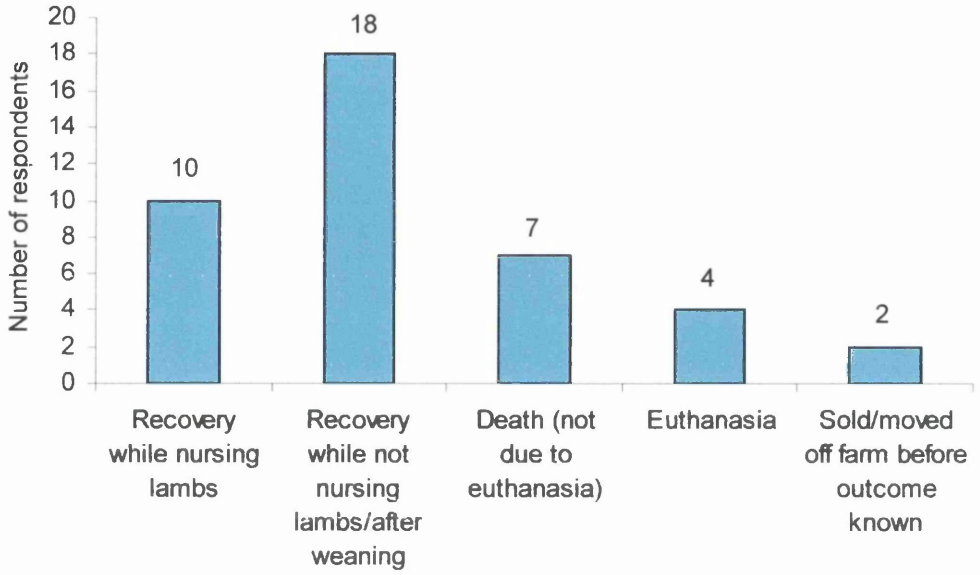


Figure 5.20. Numbers of respondents who indicated time periods elapsing between onset of cases of Kangaroo Gait in years when more than one case occurred.

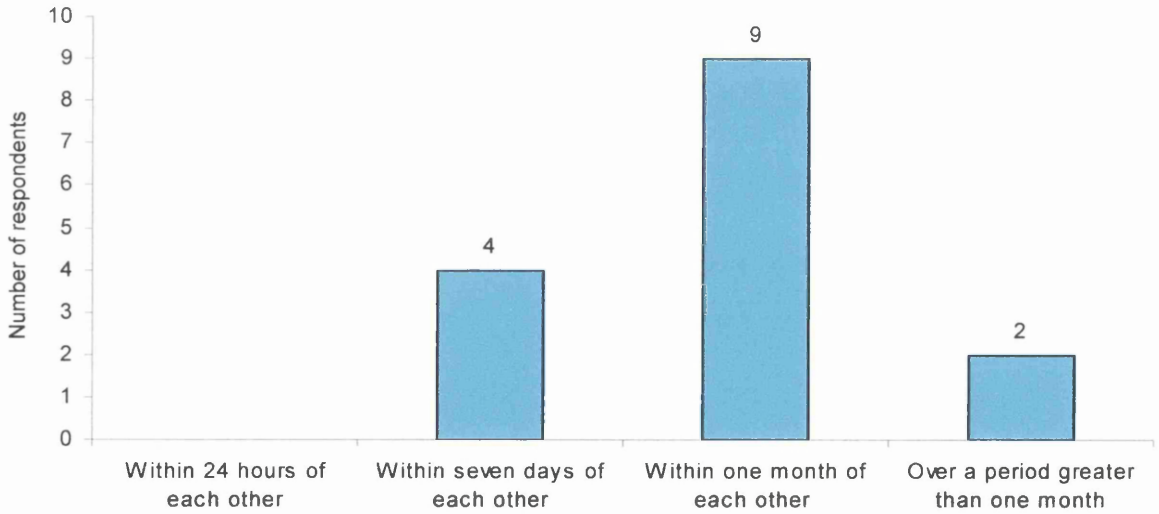
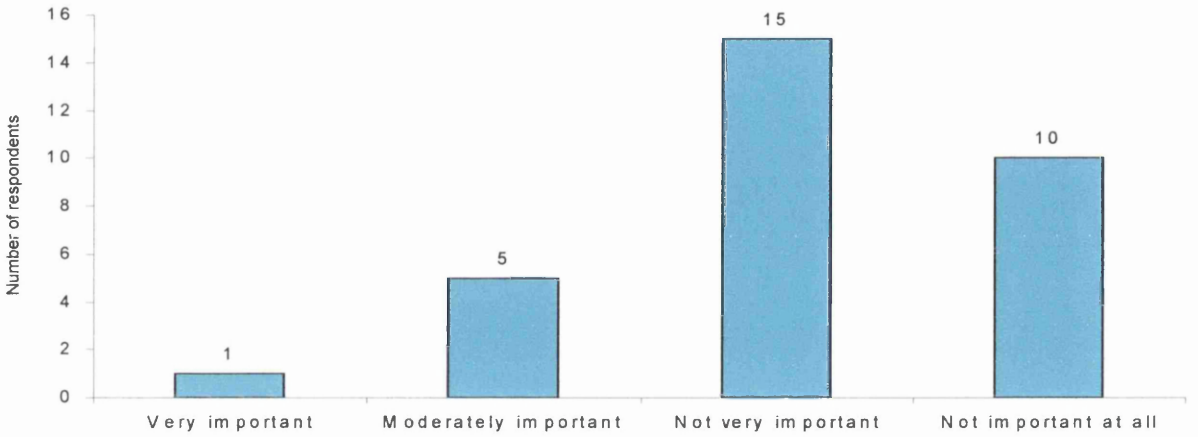


Figure 5.21. Numbers of respondents who indicated which statement best described the economic importance of Kangaroo Gait in their flocks.



5.3.2.4. Comparison of Affected and Non-Affected Flocks

The mean number of adult females in affected flocks (815.7) did not differ significantly from the mean number of adult females in non-affected flocks (758.6) ($P = 0.620$). However, the mean stocking density of affected flocks (5.89 adult sheep per hectare) was significantly greater than the mean stocking density of non-affected flocks (4.03 adult sheep per hectare) ($P < 0.05$).

Upon analysis of the data in Table 5.15., the proportions of flocks affected with Kangaroo Gait predominantly managed under lowland, upland, hill and mixed production systems were found to differ significantly ($P < 0.01$). There was no significant difference in the proportion of affected flocks managed under lowland and upland systems. A significantly greater proportion of flocks managed under mixed production systems were affected than the proportion of flocks managed under lowland, upland and hill systems combined ($P < 0.01$), but no significant difference was found when comparing the proportion of affected flocks managed under mixed production systems with those managed under lowland and upland production systems combined. A significantly lower proportion of flocks managed under hill production systems were affected than the proportion of flocks managed under lowland, upland and mixed production systems combined ($P < 0.05$).

The proportion of affected flocks was found to differ significantly when comparing flocks containing predominantly lowland, hill, commercial cross and mixed breeds ($P < 0.01$) (Table 5.16). There were no significant differences between the proportions of flocks affected when comparing flocks comprised predominantly of lowland breeds with all other flocks combined, or when comparing flocks comprised of mixed breeds with all other flocks combined. A significantly lower proportion of flocks were affected when comparing those comprised predominantly of hill breeds with all other flocks combined ($P < 0.05$). A significantly higher proportion of flocks were affected when comparing those comprised predominantly of commercial cross breeds with all other flocks combined ($P < 0.05$).

No significant difference was found in proportions of flocks affected when comparing those flocks comprised of commercial fat (or store) lamb production, commercial breeding stock production and pedigree breeding stock production enterprises (Table 5.17.). Similarly, no significant difference was found in proportions of flocks affected when comparing early, intermediate and late lambing flocks (Table 5.18.).

No significant difference was found in proportions of flocks affected when comparing flocks that are a member of one or more national disease accreditation or monitoring schemes with flocks that are not. A significantly smaller proportion of flocks having a written health plan containing details of treatment and prevention practices for lameness, were affected, when compared to flocks that did not have a written flock health plan ($P < 0.05$).

Table 5.15. Percentages of flocks affected and not affected with Kangaroo Gait, managed predominantly* under each type of production system.

Type of Production System	Percentage of Affected Flocks (%)	Percentage of Non-Affected Flocks (%)
Lowland	25.8	20.2
Upland	32.3	38.3
Hill	3.2	29.8
Mixed	38.7	11.7

* Pertains to flocks grazing pasture types comprising > 75% of the total area dedicated to sheep production.

Table 5.16. Percentages of flocks affected and not affected with Kangaroo Gait, comprised predominantly of adult female sheep from each breed group.

Breed Group	Percentage of Affected Flocks (%)	Percentage of Non-Affected Flocks (%)
Lowland breeds*	12.5	16.8
Hill breeds*	6.3	30.7
Commercial cross breed*	62.5	32.7
Mixed breeds cross breeds**	18.8	19.8

* Relates to the breed group which comprises > 65% of the number of adult female sheep in each flock.

** Flocks in which neither commercial cross breeds, lowland breeds nor hill breeds comprise >65% of the number of adult female sheep in each flock.

Table 5.17. Percentages of flocks affected and not affected with Kangaroo Gait, containing each sheep-related enterprise.

Enterprise	Percentage of Affected Flocks (%)	Percentage of Non-Affected Flocks (%)
Commercial fat or store lamb production	100.0	92.0
Commercial breeding stock production	46.9	38.0
Pedigree breeding stock production	31.3	30.0

Table 5.18. Percentages of flocks affected and not affected with Kangaroo Gait, classified as being early (lamb on or before 7 March), intermediate (lamb between 7 March and 1 April) and late (lamb on or after 1 April) lambing.

Classification by Date of Commencement of Lambing	Percentage of Affected Flocks (%)	Percentage of Non-Affected Flocks (%)
Early	25.0	12.9
Intermediate	43.8	41.6
Late	31.3	45.5

Table 5.19. Percentages of flocks provided veterinary care by each practice, in each size category, in the DSVS study area, and in the Scottish Borders, as indicated by veterinary surgeons and sheep flock owners and managers.

	Northern Britain (Excluding The Scottish Borders)	The Scottish Borders	
Number of Adult Breeding Females	Percentage of Flocks (%) According to:	Percentage of Flocks (%) According to:	
	Veterinary Surgeons	Veterinary Surgeons	Flock Owners and Managers
< 50	15.5	2.1	3.7
50-250	39.1	6.6	14.8
250-500	28.1	23.7	17.0
> 500	17.3	67.6	64.4

5.3.2.5. Comparison of Results of the Demographic Studies of Veterinary Surgeons of Northern Britain and Sheep Flock Owners and Managers of the Scottish Borders.

The proportions of flocks in each size category (relating to numbers of adult breeding females) differed significantly between the Scottish Borders and the rest of the DSVS study area ($P < 0.001$) (Table 5.19). No significant difference was found between the proportions of flocks with < 50 adult females and 50-250 adult females when comparing the Scottish Borders and the rest of the DSVS study area. A significantly greater proportion of flocks in the Scottish Borders had >250 breeding females when compared to the rest of the DSVS study area ($P < 0.001$). The proportion of flocks with >500 adult breeding females was also significantly greater for the Scottish Borders ($P < 0.001$) when compared to the rest of the DSVS study area.

In order to analyse and compare the responses of veterinary surgeons in the DSVS and sheep flock owners and managers, it was necessary to combine flocks containing <50

and 50–250 adult female sheep. Veterinary surgeons in the DSVS indicated that 45 flocks in the Scottish Borders contained <250 adult breeding females, and sheep flock owners and managers indicated that 25 flocks contained <250 adult breeding females. The proportions of flocks in the Scottish Borders in each size category differed significantly when comparing estimates made by veterinary surgeons in the DSVS and responses of flocks owners or managers ($P < 0.01$) (Table 5.20). No significant difference was found in the proportions of flocks comprised of 250-500 or > 500 adult breeding sheep when comparing responses from veterinary surgeons and sheep flock owners and managers. The proportion of flocks containing <250 adult breeding females was significantly lower according to the estimates made by veterinary surgeons in the DSVS when compared to the proportion owned or managed by respondents in Chapter 5 ($P < 0.01$).

The proportions of flocks predominantly managed under lowland, upland and hill production systems varied significantly between the Scottish Borders and the rest of the DSVS study area ($P < 0.001$), and within the Scottish Borders, when comparing responses of veterinary surgeons in the DSVS and flock owners and managers ($P < 0.001$) (Table 5.20). According to veterinary surgeons, a significantly smaller proportion of flocks in the Scottish Borders were managed under lowland production systems ($P < 0.001$) and a significantly greater proportion were managed under upland production systems ($P < 0.001$), when compared to the rest of the DSVS study area. No significant difference was found in the proportion of flocks managed under hill production systems when comparing responses of veterinary surgeons in the Scottish Borders and the rest of the DSVS study area. Sheep flock owners responding to the survey in Chapter 5 indicated that a significantly greater proportion of their flocks were managed under lowland production systems than was indicated by veterinary surgeons in the DSVS ($P < 0.001$), however there was no significant difference in the proportions of flocks managed under both upland and hill production systems when comparing responses from the two groups. In the Scottish Borders, sheep flock owners and managers indicated that a significantly greater proportion of their flocks were affected with Kangaroo Gait when compared to estimates made by veterinary surgeons in the DSVS ($P < 0.001$) (Table 5.21).

Table 5.20. Percentages of flocks provided veterinary care by each practice, managed predominantly under each production system (topographic type), in the DSVS study area, and in the Scottish Borders, as indicated by veterinary surgeons and sheep flock owners and managers.

	Northern Britain (Excluding The Scottish Borders)	The Scottish Borders	
Production System	**Percentage of Flocks (%) According to:**	**Percentage of Flocks (%) According to:**	
	Veterinary Surgeons	**Veterinary Surgeons**	**Flock Owners and Managers**
Lowland	30.6	8.7	25.6
Upland	37.8	58.5	47.2
Hill	31.6	32.8	27.2

* Predominant production system relates to the type of pasture which comprises > 50% of the area dedicated to sheep production in each flock.

Table 5.21. Percentages of flocks in the Scottish Borders affected and not affected with IFP, according to veterinary surgeons (as indicated in the DSVS) and sheep flock owners and managers.

	The Scottish Borders	
	Veterinary Surgeons	**Flock Owners and Managers**
Percentage of flocks affected (%)	3.5	24.1
Percentage of flocks not affected (%)	96.5	75.9

5.4. SUMMARY

The overall useable response rate was 30.7%, although the number of item non-responses varied between questions. In total, respondents provided information on 134 flocks, containing approximately 144 934 sheep, including 101 775 breeding female sheep. The most numerous breeds among breeding female sheep were the Greyface Mule, the Scottish Blackface, the Scottish/English Mule and the Cheviot. There were approximately even numbers of commercial cross breed and hill breed breeding female sheep. Most flocks produced commercial fat lambs, although some commercial and pedigree breeding stock production occurred. The study area was comprised mostly of hill and upland pasture, but the number of (predominantly) lowland and hill farms was similar, and somewhat less than the number of (predominantly) upland farms. Lambing occurred in most flocks between mid-March and early May, although a significant number of early lambing flocks existed. Weaning dates varied widely, although most flocks weaned lambs between mid-July and mid-October. Housing, whether 24 hours per day or less than 24 hours per day, commenced between mid-November and mid-April, and turnout occurred between early February and late May. A large number of flocks were not housed during the winter months.

Few flocks belonged to national disease accreditation or monitoring schemes, although almost 30% of respondents indicated that they had a written flock health plan containing details of prevention and treatment of lameness. Most respondents indicated that the number of veterinary visits they received in 1999 represented no significant change when compared to the average number of veterinary visits received during the previous five years, and that there was no change in likelihood that they would request veterinary attention to a diseased sheep. Few respondents used vaccines for the prevention of lameness, but most respondents kept antibiotics for the treatment of lame sheep. The most commonly kept antibiotics were various oxytetracycline preparations. Interdigital lesions were indicated to be the most common cause of abnormal locomotion, and weakness of the forelimbs accounted for 0.5% of cases of abnormal locomotion. Only 6.7% of sheep affected with forelimb weakness received veterinary attention in 1999. The most important criterion in deciding on whether or not respondents would request veterinary attention to diseased sheep was the degree of pain and discomfort

experienced by the sheep, followed by concern that other sheep may become affected, and the level of confidence of the respondent that they could treat the condition without veterinary assistance.

Fourteen respondents indicated that they had had animals affected with Kangaroo Gait in their flocks for which veterinary attention was sought, and 30 respondents indicated that cases had occurred for which no veterinary attention was sought. In total, 24.1% of respondents indicated that cases of Kangaroo Gait, or of a locomotor disorder with similar presenting signs, had occurred in their flocks at some time. Respondents indicated that, on average, over four cases of Kangaroo Gait would have to occur before they would seek veterinary attention. There appeared to be an increase in the number of cases of this condition since 1990, with a small increase noted in each of the last three years. Most affected animals belonged to commercial cross breeds, were breeding females, and had been initially affected during pregnancy or lactation. If affected during lactation, most were suckling twin lambs. Onset of clinical signs occurred frequently during the spring months (May-June), and most cases occurred while sheep were at grass. Recovery was noted in breeding female sheep both prior and subsequent to weaning of the lambs. If more than one case occurred in any year, most respondents indicated that onset occurred within one month, but over a period of greater than one week. Most respondents considered Kangaroo Gait to be of little or no economic importance in their flock.

Significantly greater proportions of flocks managed under mixed production systems, and containing commercial cross breeds, were affected with Kangaroo Gait. Significantly lower proportions of flocks managed under hill production systems, containing predominantly hill breeds of sheep, and for which a flock health plan containing details of lameness treatment and prevention, were affected. According to veterinary surgeons, the Scottish Borders had significantly greater proportions of flocks containing >250 and >500 adult breading females and flocks managed under upland production systems, and a significantly smaller proportion of flocks managed under lowland production systems, than the rest of Northern Britain. Analysing responses of flock owners and managers and veterinary surgeons in the Scottish Borders region showed that the latter group estimated that this region contained significantly smaller

proportions of flocks comprised of <250 adult breeding females, and managed under lowland production systems when compared to the estimates of the former. A significantly greater proportion of flocks owned or managed by respondents to the survey in Chapter 5 had had one or more cases of a locomotor disorder resembling Kangaroo Gait when compared to the proportion of flocks in the Scottish Borders indicated by veterinary surgeons to have had one or more cases of this condition.

5.5. DISCUSSION

A lower response rate was achieved compared to the DSVS, which may reflect the fact that it was not possible to pretest the questionnaire to the same extent, or to conduct follow-up mailings. Additionally, the nature of the subjects differed between the two surveys, and this was likely to have influenced the response rate. Levels of literacy, availability of time to complete the questionnaire (February and March tend to be busy times of the year in Scottish farming), despondency owing to the contemporary economic depression of the UK sheep industry, reluctance to divulge information relating to diseased sheep in their flocks, and negative preconceptions relating to the value of veterinary research, the low economic importance of Kangaroo Gait, and the expected level of difficulty encountered in completing the questionnaire document, were all potential characteristics of the subjects which may have reduced their motivation for returning a completed questionnaire. The questionnaire document was eight pages long, containing 34 questions and requiring up to 146 responses. The length of the questionnaire may have been off-putting to some potential respondents, although Dillman (1978) claims that questionnaire lengths up to 12 pages and 125 items should not adversely affect response rates. Non-responses were likely to be a highly significant source of bias in the survey results. In particular, it was thought that flock owners or managers who had never had sheep in their flocks demonstrating clinical signs similar to those of Kangaroo Gait, or who had never had cases in their flocks diagnosed by veterinary surgeons, would have been less likely to respond. This may have been due to disinterest in the topic, or a perception that information they could provide would be of little value. The result would have been an overestimation of the proportion of affected flocks. Nevertheless, it was impossible to assess either the presence or magnitude of any bias. Bourque and Fielder (1995) claim that, in the absence of any follow-ups,

response rates of less than 20% can be expected in self-administered mail surveys. In this light, the response rate of approximately 30% achieved in this survey was not considered disappointing or unexpected. Consideration of the number of respondents as a proportion of the number of flocks in the Scottish Borders, according to either the DSVS veterinary surgeons or the 1999 June agricultural census, must be done with care. A number of respondents indicated that their flocks were located in regions neighbouring the Scottish Borders (Northumberland, Dumfries and Galloway, the Lothians, Strathclyde), and it was likely that many flocks located in the Scottish Borders receive veterinary care from practices located in these neighbouring regions.

Misclassification of cases of Kangaroo Gait was considered to be one of the most important potential sources of error, owing to the absence of veterinary clinical training among the subjects of the survey. As with the DSVS, descriptions of the distinguishing features of Kangaroo Gait were provided, both in the covering letter and the questionnaire document. Additionally, one major purpose of question 18, which related to the occurrence of a range of locomotor disorders in the flock, was to highlight the differences between Kangaroo Gait and other common locomotor disorders, in order to assist respondents in accurately identifying cases of this condition. Kangaroo Gait was provided as the sole example of a disorder causing weakness of the forelimbs. Implicit in this question was that, unlike other locomotor abnormalities, Kangaroo Gait is not associated with lesions of the interdigital tissue, hoof, skin or udder, joints, or bones, nor is it associated with pain, gait abnormalities of the hind limb or trauma. This question required a large input from the respondent, and may have discouraged some respondents from completing the questionnaire; however it was considered to be a necessary inclusion owing to the anticipated problems of misclassification. A further consideration was that, as with the DSVS, atypical cases of Kangaroo Gait, possibly including adult males, lambs, non-reproductive females, or sheep affected with concurrent diseases, may not have been identified, leading to total or item non-responses.

The major aims of the Demographic Survey Among Sheep Flock Owners and Managers of the Scottish Borders were to validate the results of the DSVS, to attempt to quantify the proportion of cases of Kangaroo Gait that were not reported to veterinary surgeons,

and to obtain more detailed information pertaining to individual sheep and flocks affected by, and at risk of developing, this condition. Comparisons of the responses of veterinary surgeons from the Scottish Borders and the rest of the DSVS study area were made. A significantly greater proportion of flocks in the Scottish Borders contained greater than 250 breeding females, and were managed under upland production systems, when compared to the rest of Northern Britain. This implied that flocks in the Scottish Borders may not have been representative of flocks in the rest of Northern Britain, suggesting that extrapolations made from data collected from flocks in this region to the rest of Northern Britain, must be made with great care. Similarly, comparisons between responses of sheep flock owners and managers and veterinary surgeons in the Scottish Borders revealed significant differences. Sheep flock owners and managers provided information relating to a significantly smaller proportion of flocks with greater than 250 breeding females, and a significantly greater proportion of flocks managed under lowland production systems, when compared to the estimates made by veterinary surgeons in the DSVS. This may suggest that flocks owned or managed by respondents to the survey document in Chapter 5 may not be representative of all flocks in the Scottish Borders, or it may indicate that validity of responses made by veterinary surgeons in the DSVS to these questions was poor.

Of the 32 respondents who indicated that cases of a locomotor disorder resembling Kangaroo Gait had occurred in their flocks, 18 (56.3%) indicated that they had not sought veterinary attention for affected sheep, and of the remaining 14, 12 respondents (37.5%) indicated that, although veterinary attention had been sought for one or more cases of Kangaroo Gait, no veterinary attention had been sought for other affected individuals. This suggests that calculations based on numbers of cases examined by or reported to veterinary surgeons would lead to a substantial underestimation of the occurrence of this condition. Although extrapolations of the results of this survey to the DSVS study area must be undertaken with care, the results of this survey would suggest that more than double the number of flocks in Northern Britain may have been affected with Kangaroo Gait than was estimated by respondents in the DSVS. Sheep flock owners and managers stated that, on average, 4.2 cases of Kangaroo Gait would have to occur in their flocks before veterinary attention would be sought. As Kangaroo Gait affects a small percentage of sheep within a flock, rarely amounting to more than one or

two sheep per year, it seems likely that veterinary surgeons would not be aware of the occurrence of this condition in the majority of affected flocks.

Fourteen flocks were indicated to have had one or more cases of Kangaroo Gait either examined by, or reported to, veterinary surgeons, both according to respondents in the DSVS and sheep flock owners and managers. Respondents in the DSVS indicated that, of these 14 flocks, four were predominantly managed under lowland production systems, and ten under upland production systems. According to sheep flock owners and managers, the same number of affected flocks were managed under lowland production systems (four), however, of the remaining ten flocks, five were managed under mixed upland/hill production systems, two were managed under upland production systems, and one each were managed under mixed lowland/hill and lowland/upland production systems. No response was given by one respondent relating to the type of production system under which his/her flock was managed. These results suggest that responses made by veterinary surgeons relating to the number and type of flocks from which they had examined or received reports of Kangaroo Gait were accurate, given the limitations of the response categories provided in the DSVS. However, there was a difference between types of respondent in recalling the year in which the first case of Kangaroo Gait was diagnosed in the Scottish Borders – veterinary surgeons indicated that the first case was diagnosed in 1980, and flock owners and managers indicated that the first case was diagnosed in 1984. This may suggest that recall bias was a potential source of error in the surveys, particularly in relation to events that occurred in the more distant past.

Many features of affected animals and flocks were similar when comparing responses in the two surveys. In both surveys, commercial cross breeds were identified as the breed group most commonly affected, in particular the Greyface Mule and the Scottish/English Mule breeds. Analysis of the results in the Demographic Survey of Sheep Flock Owners and Managers of the Scottish Borders showed that flocks predominantly comprised of commercial cross breeds were more likely to be affected than other flocks, and those predominantly comprised of hill breeds were less likely to be affected than other flocks. These results raise the possibility that breed predisposition

(among commercial cross breeds) or breed resistance (among hill breeds) may exist for Kangaroo Gait.

In the DSVS, upland flocks were most commonly affected, followed by lowland flocks and hill flocks. In the Demographic Survey of Sheep Flock Owners and Managers of the Scottish Borders, flocks managed under mixed production systems were more likely to be affected than other flocks, and hill flocks were less likely to be affected. Within the UK sheep industry, particular breeds are considered more suitable for certain topographically defined production systems, and specific breeds often predominate in areas comprised of the relevant pasture types. In Northern Britain, commercial cross breeds, such as the Greyface Mule, typically graze upland pastures, whereas hill breeds, such as the Scottish Blackface and the Swaledale, typically graze hill pastures. The question arises: is the apparent difference in occurrence of Kangaroo Gait between lowland, upland and hill flocks due to production system-related factors, such as stocking density, management practices, or meteorological influences, or is it a result of differences in susceptibility between breeds which are typically managed under related production systems? The results of this study do not provide a firm answer to this question, although the use of multivariable analytical methods may have allowed for the relative contribution of these factors to be more clearly elucidated. These methods have not been explored in this study.

Another similarity in the results of the two surveys is the apparent increase in numbers of individuals and flocks affected by Kangaroo Gait in the years since it was first identified, with a much larger number reported to have been affected in the years 1997-1999 when compared to the years 1990-1996 and the preceding period. In both surveys this may represent an actual increase in the occurrence of Kangaroo Gait, possibly owing to alterations in management practices, meteorological changes, or the spread of some form of infectious aetiological agent. Alternatively, this apparent increase may be due, in part, or in full, to an element of recall bias.

In both surveys, over 95% of respondents indicated that Kangaroo Gait had occurred in adult female sheep, and a small proportion indicated that cases had occurred in tups, lambs and wethers (the latter in the DSVS only). In both surveys, over three quarters of

the respondents indicated that onset of clinical signs in adult females had occurred during lactation, with approximately one quarter of respondents indicating that onset had occurred in one or more adult females during late pregnancy, and a small number indicating that onset had occurred between weaning and tupping. These results support the findings of Moffat, (1978), Duffel and others, (1986), Barlow and Greig, (1986), and Clarkson, (1991), who identified this condition in lactating or pregnant adult females. The small number of contradictory responses may have represented misclassification, inaccurate anamneses, or correctly classified atypical cases. In both surveys, over three quarters of the respondents indicated that, in years in which one or more cases of Kangaroo Gait occurred, it affected, on average, less than 0.5% of the adult females in the flock. No respondents in either survey indicated that the condition affected, on average, greater than 2.0% of the flock.

One difference in the results of the two surveys was the perception of the economic importance of Kangaroo Gait to owners of affected flocks. The majority of veterinary surgeons perceived that Kangaroo Gait may have been of at least some importance to owners of affected flocks, whereas most owners and managers of affected flocks considered this condition to be of little or no economic importance. It is possible that, to some extent, this difference in attitude between classes of respondent may have contributed to the different response rates, and also to some of the discrepancies between the results, of the two surveys.

Additional information was sought from flock owners and managers in this survey that was not sought from veterinary surgeons in the DSVS. Very few respondents indicated that Kangaroo Gait occurred in individual sheep in more than one year. In most flocks, onset of cases of Kangaroo Gait had occurred in the months March-June, and while sheep were at grass. These findings were not surprising, as they were consistent with the time of year during which adult female sheep in the study area were in either lactation or late gestation. The mean numbers of adult females did not differ between affected and non-affected flocks, however the mean stocking density was significantly greater in affected than in non-affected flocks.

A number of factors, relating to general and specifically health-related management practices, were examined for any possible statistical association with the occurrence of Kangaroo Gait. The undertaking of different sheep related enterprises did not appear to be associated with the occurrence of Kangaroo Gait, nor was the classification of flocks as early, intermediate or late lambing flocks, based on the date on which lambing commenced. A minority of flocks were members of national disease accreditation or monitoring schemes, and no association was found between membership of these schemes and the occurrence of Kangaroo Gait. A high percentage of respondents possessed written flock health programmes containing details of prevention and treatment of lameness, which in many cases was probably as a result of fulfilling the requirements of various flock health schemes. It appeared that respondents who possessed a written health plan were less likely to have had one or more cases of Kangaroo Gait in their flocks. A possible explanation for this finding could be that, among owners and managers of flocks that had never had cases of Kangaroo Gait in their flocks, subjects who possessed written flock health plans were more likely to respond to the survey than those who did not. This may have been a reflection of higher standards of management, and greater motivation to respond to the questionnaire. Alternatively, it may have reflected a negative association between higher standards of lameness treatment and prevention and the occurrence of Kangaroo Gait, or conditions that may be misclassified as Kangaroo Gait, such as foot rot.

The issue of welfare is becoming increasingly important in UK farming industries, particularly as the contemporary economic depression of the UK farming industries has led to fears that, owing to their marginal value, fewer diseased sheep may have received veterinary attention. Evidence was provided that farmers were aware of the importance of welfare, with the degree of pain and discomfort experienced by diseased sheep being considered the most important criterion in making a decision to request veterinary assistance, by the largest number of respondents. Other evidence included the prevalence of written flock health programmes and the fact that, despite the downturn in the economic fortunes of the UK sheep industry in recent years, the majority of sheep owners and managers claimed to be no less likely to request veterinary attention for diseased sheep. This evidence must be considered in light of the possibility that, rather than providing responses indicative of true situations, many farmers may have provided

responses that they perceived to be acceptable or desirable to the administrators of the survey, or to members of the general public. It remains true that veterinary attention was sought for only 2.3% of all sheep with locomotor disorders in 1999, and that, rather than requesting veterinary attention, the majority of farmers choose to keep antibiotics on-farm for the treatment of lameness. In the light of these findings, the fact that the ability of the farmer to make his/her own diagnosis was the third most highly ranked criterion in deciding to request veterinary attention for diseased sheep, may imply that farmers possess a high level of confidence in their own ability to make decisions pertaining to diagnosis and therapy. The finding that financial considerations were considered less important than welfare, the risk of spread of disease to other sheep, and the farmer's own ability to make a diagnosis, suggests a pragmatic, rather than a parsimonious approach to involvement of veterinary surgeons. It would seem highly unlikely that farmers would request veterinary attention for cases of Kangaroo Gait if they were aware, from previous experience, that affected animals were likely to recover without serious consequences to the welfare or economics of the flock. It is likely that veterinary attention would only be sought in situations where farmers have had no previous experience of the condition, and they have concerns regarding the welfare of affected animals, the possibility of spread of the condition to other members of the flock, and a lack of confidence in their own ability to make a diagnosis. One concern arising from the knowledge that a minority of cases of locomotor disorders are reported to veterinary surgeons, is the possibility that the introduction of exotic diseases, such as foot and mouth disease, bluetongue, and rabies, may go initially undetected, allowing them to become more widely established. This study has, therefore, highlighted many of the problems associated with relying upon veterinary surgeons and farmers for the provision of information for the purposes of disease surveillance and monitoring.

In summary, the results of the Demographic Survey of Sheep Flock Owners and Managers of the Scottish Borders suggest that there was a reasonable degree of validity in the responses of veterinary surgeons relating to the details of cases examined by or reported to them. However these results suggest that, owing to underreporting of this condition to veterinary surgeons, any estimates of the number of affected individuals and flocks based on information gained from veterinary surgeons would under-represent the true occurrence of this condition.

CHAPTER 6

GENERAL DISCUSSION

6.1. DISCUSSION

In this study, information relating to a distinct, but previously poorly described locomotor disorder of sheep, termed Kangaroo Gait, was collected using a range of methods. The basic principles of obtaining and analysing samples from individuals or populations, and subsequently making inferences from the results of these analyses, were common features of each of the components of this study. A primary aim of the study was to attempt to confirm or refute the findings of the few published clinical and pathological reports of Kangaroo Gait, and in doing so, to achieve further definition of what constitutes a case of this condition. Aspects of the clinical and pathological investigations undertaken for this purpose were to identify the signalment, anamnesis, physical changes (including the neurological changes), alterations in concentrations of electrolytes, enzymes, trace elements and vitamins in circulating blood, and serological responses to viral agents, in affected animals.

Many features of the signalment and anamneses of animals examined in this study were found to be consistent with those in previous reports. Affected individuals were adult female sheep, and onset occurred during late gestation or early lactation. Owners of affected sheep reported that spontaneous recovery occurred, however, unlike in previous reports, a number of owners reported that recovery occurred while affected sheep were nursing lambs. If this feature of the condition was to be confirmed, the suggestion that recovery from Kangaroo Gait was dependent on cessation of lactation could be challenged (Moffat, 1978; Barlow and Greig, 1986; Down, 1986). Other findings of this study that represented additions to previous knowledge of this condition were that Kangaroo Gait could occur in female sheep as young as 12 months of age, and as old as seven years of age, and that a range of breeds and cross breeds were susceptible. Additional features of the anamneses of affected individuals and flocks were unremarkable. Apart from the gait abnormality and associated neurological deficits, a physical examination did not find consistently any abnormalities in affected sheep. Additionally, ancillary investigations did not reveal consistently any significant abnormalities. Unfortunately, owing to ethical considerations, it was not possible to obtain clinical data from control animals from the same flocks as the affected individuals.

An understanding of the functional anatomical basis of the neurological system allowed for lesions within this system to be located via a neurological examination. In doing so, Kangaroo Gait was differentiated from a range of neurological disorders that affect sheep and other ungulates. In all thirteen sheep examined, findings of paresis of both of the forelimbs, with evidence of specific extensor muscle weakness, suggested a bilateral disorder of the radial nerves. Additional findings were variable, which was not surprising considering that results of neurological examinations of clinically normal sheep vary (Hoffmeyr, 1978). Proprioceptive deficits were present in three moderately or severely affected animals, but were absent in other, more mildly affected sheep, and forelimb flexor withdrawal reflexes were intact for three cases. Although these results did not rule out the possibility of upper motor neurone (UMN) involvement in the pathogenesis of Kangaroo Gait, it is likely that the abnormal neurological findings were due to a peripheral neuropathy of the radial nerve, or a neuromuscular disorder affecting the radial nerve and the muscles that it supplies. In summary, a case of Kangaroo Gait was defined clinically as a sudden onset locomotor disorder, with onset in adult female sheep during late gestation or lactation, characterised by bilateral forelimb paresis, with neurological changes suggestive of radial nerve dysfunction. In order to confirm or refute the location of the causative lesion, as determined by the clinical investigation, it was necessary to undertake a pathological investigation of a number of affected individuals.

Other than the sparse non-specific changes evident in the radial nerves of one case, none of the pathological changes described in the radial nerves by Duffell and others (1986) and O'Toole and others (1989) were found in the three cases examined, where onset of clinical signs had occurred during gestation. However, according to the case records of one sheep that had been affected during lactation, Wallerian degeneration was present in both of the radial nerves, albeit not extensively. This may have cast doubt on the validity of including onset during gestation among the features that define cases of Kangaroo Gait. It was argued, however, that many neurological disorders are associated with spectrums of pathological changes that do not account for their distinct clinical characteristics. Examples of such disorders include laryngeal hemiplegia and stringhalt of the horse. Mild, non-specific changes were detected in the spinal cords of two cases, and in the brain of one case, which may support the suggestion that Kangaroo Gait has a CNS component, however no control animals from the same flocks

were examined pathologically in order to exclude the possibility of concurrent disease. More detailed studies are required before conclusions can be reached regarding the precise range of pathological changes associated with Kangaroo Gait.

Further aims of this study were to measure the number and geographical distribution of affected individuals and flocks in defined study areas, and to assess the economic importance of the condition. Two questionnaire surveys were planned and executed with these aims in mind. The first questionnaire survey was mailed to veterinary surgeons in all practices in Northern Britain which, according to The Directory of Veterinary Practices (Hall, 1996), provided veterinary care for sheep. A high response rate was achieved, owing to the efforts placed in pretesting the questionnaire and undertaking carefully timed follow-ups.

In total, 29.7% of respondents indicated that members of their practice had examined or received reports of at least one case of Kangaroo Gait. This condition had been identified in all regions except Cleveland, and it appeared that there was a greater concentration of practices in which cases had been identified in the Southern and Central regions of Scotland and the bordering areas of North East England. Almost all respondents who indicated that members of their practice had examined or received reports of Kangaroo Gait indicated that affected animals included adult female sheep. A small number indicated that they had examined or received reports of the condition in tups, lambs and adult wethers, possibly a reflection of inaccurate classification of Kangaroo Gait, or possibly a result of Kangaroo Gait truly occurring in these classes of sheep. A high proportion of respondents indicated that adult female sheep had been affected during early and mid/late lactation, with fewer numbers of respondents indicating that adult female sheep had been affected during late pregnancy, and a small number indicating that cases had occurred during early pregnancy or between weaning and tupping. Commercial crosses appeared to be most commonly affected breed group among sheep in this study, in particular the Greyface and the Scottish/English Mule breeds. Slightly less than one percent of the flocks that received veterinary care from respondents to this survey had been affected and a significantly greater proportion of lowland and upland flocks were affected than hill flocks. The first case of Kangaroo Gait had been diagnosed in the study area in 1976. Since then it appears that the average annual number of flocks identified as being affected has risen greatly, although

estimates may have been influenced significantly by recall bias. A majority of respondents indicated that in years during which Kangaroo Gait occurred, it affected, on average, less than 0.5% of the number of adult female sheep in the flock, which is consistent with previous reports. In general, respondents indicated that Kangaroo Gait was not economically important to their local sheep industries, but the majority considered this condition to be at least of some economic importance to owners of affected sheep.

It was thought that, for a variety of reasons, an unknown number of cases of Kangaroo Gait would have occurred which were not examined by, or reported to veterinary surgeons, leading to an underestimation of the number of flocks affected by Kangaroo Gait in the first questionnaire survey. In an attempt to estimate the magnitude of this underestimation, to obtain more accurate and detailed information pertaining to individual cases of Kangaroo Gait, and the management of flocks from which cases of Kangaroo Gait come, and to attempt to assess the quality of the first questionnaire survey, particularly the validity of the survey, it was decided to undertake a second questionnaire survey of sheep flock owners and managers located in the Scottish Borders. Sheep flock owners and managers were recruited via veterinary surgeons who responded to the first questionnaire survey. This practice resulted in limitations on the possible number of follow-ups that could be implemented, and created problems relating to the inability to select the respondents directly. Subjects were asked to provide information pertaining to the size, location, structure, breeds, grazing systems, housing and lambing dates, and various aspects of health management of their flocks, in addition to information specifically relating to Kangaroo Gait.

A lower, but anticipated, response rate was achieved. Results indicated that 10.4% of respondents had had animals affected with Kangaroo Gait in their flocks for which veterinary attention was sought, and a total of 24.1% of respondents indicated that cases of Kangaroo Gait, or of a locomotor disorder with similar presenting signs, had occurred in their flocks at some time. As with the first survey, there appeared to be an increase in the number of cases of this condition since 1990, with a small increase noted in each of the last three years. Most affected animals belonged to commercial cross breeds, were breeding females, and had been initially affected during pregnancy or

lactation. If affected during lactation, most were suckling twin lambs. Significantly greater proportions of flocks managed under mixed production systems, and containing commercial cross breeds, were affected with Kangaroo Gait. Significantly lower proportions of flocks managed under hill production systems, containing predominantly hill breeds of sheep, and for which a flock health plan containing details of lameness treatment and prevention, were affected. Onset of clinical signs occurred frequently during the spring months (March-June), and most cases occurred while sheep were at grass. In support of the clinical investigation, and the results of the first survey, recovery was noted in breeding female sheep both prior and subsequent to weaning of the lambs. If more than one case occurred in any year, most respondents indicated that onset occurred within one month, but over a period of greater than one week. Most respondents considered Kangaroo Gait to be of little or no economic importance in their flock. A significantly greater proportion of flocks owned or managed by respondents to the second survey had had one or more cases of a locomotor disorder resembling Kangaroo Gait when compared to the proportion of flocks in the Scottish Borders indicated by veterinary surgeons to have had one or more cases of this condition. Comparing the results of the two surveys suggested that the validity of responses in the first survey was good when considering the characteristics of animals affected with Kangaroo Gait, but that recall bias was potential source of error when considering information relating to events that occurred in the distant past. The success of these surveys confirmed that mailed questionnaires are a useful method for veterinary data collection.

No attempt was made to determine the aetiology of Kangaroo Gait. Knowledge of the aetiology of this condition would allow measures to be taken to prevent its occurrence. As this condition is characterised clinically by gradual recovery and pathologically by regeneration, it seems likely that examinations performed weeks to months after the onset of clinical signs would result in different findings to those performed immediately prior to, at the time of, and immediately after, the onset of this condition. Such investigations have never been undertaken. In order to determine the aetiology of Kangaroo Gait, close observation of animals around the time of onset of clinical signs, and recruitment of individuals for clinical and pathological examinations at that time, would be essential. Further epidemiological investigations could prove useful in determining risk factors for the occurrence of Kangaroo Gait. However, in the opinion

of the author, the problems encountered in this study of accurately defining cases of Kangaroo Gait, and the need to determine an aetiological agent, confer a secondary degree of importance on the application of epidemiology when compared to the likely benefits of future clinical and pathological studies. In any case, economic crises in the UK sheep industry, accompanied by a general perception that Kangaroo Gait is of little economic importance, make it unlikely that investments will be made in order to study this condition in the foreseeable future. Additionally, it seems unlikely that, even if the aetiology was known, it would be economically prudent to alter management significantly to prevent or control this condition. A caveat to this statement is that, if it was eventually to be proven that the occurrence of Kangaroo Gait was symptomatic of an underlying health problem, with ramifications relating to the welfare or productivity of the flock, such investments may be warranted.

APPENDIX 1

HISTORY SHEET

Clinical Investigations of Kangaroo Gait

History Sheet

Date...../...../.....

Question 1. a. What is the postcode of your farm?.....

b. Contact Details (Optional). Name.....

Address.....

.....Telephone/Fax.....

c. What livestock other than sheep do you have on your farm?

.....

d. What area of your land is dedicated to sheep production? (number of acres/hectares).....

e. How many of the following types of sheep do you have?

Adult Tups.....

Breeding ewes>5years.....

Breeding ewes 3-5 years.....

Breeding Gimmers.....

This year's lambs.....

Previous year's lambs.....

Other.....

f. How many adult breeding female sheep of each breed do you have?

Breed:.....Number.....

Breed:.....Number.....

Breed:.....Number.....

Breed:.....Number.....

Question 2. a. Have you had any cases of Kangaroo Gait diagnosed in your flock by your veterinarian? (Y/N)

b. When was the first case diagnosed? (Month/Year...../.....

c. Have you had any cases of this disease in your flock not seen by your veterinarian? (Y/N)

d. When did the first of these cases occur? (Month/Year...../.....

e. How many cases of this disease have you had in your flock in each of the following years?

1999.....
1998.....
1997.....
1996.....
1991-1995 (estimate).....
1980-1990 (estimate).....
Before 1980 (estimate).....

f. Please write the age and breed of all sheep having had this disease since 1980.....
.....

g. Have any sheep with this condition had second or subsequent episodes during later years? (Y/N)

h. If yes (2g.), how many sheep have had repeated episodes?.....

i. How many sheep with this condition have recovered?.....

j. How many sheep with this condition have died?.....

k. How many sheep with this condition were euthanased/moved off farm before the outcome was known?.....

l. How many of these sheep were initially affected during lactation?

.....

m. How many of these sheep were affected during late pregnancy (last 8 weeks)?.....

n. How many of these sheep were affected during the dry period / early pregnancy?.....

o. How many lambs (live + dead) did each case have on the year they were affected?.....

p. How many lambs survived to weaning from each case?.....

.....

Question 3. a. What date did lambing commence in the 1998/1999 season?

Day/Month/Year)...../...../.....

b. How long was the lambing period?.....

c. What was the average body condition score of ewes at tupping?

.....

d. What was the average body condition score of ewes at lambing?

.....

e. Describe any changes to approximate lambing date, length of lambing period or average flock body condition at tupping or lambing at any time since 1990?.....

.....

Question 4. a. Between what dates were sheep housed during the 1998/1999 winter?

(D/M/Yr - D/M/Yr)...../..... /.....-...../...../.....

Question 5. a. Is your flock accredited for any diseases (e.g., Maedi-Visna, Enzootic Abortion, etc)?.....

b. How many cases of pregnancy toxaemia (twin lamb disease, ketosis) have you had in your flock this year?.....

c. How many cases of hypocalcaemia (lambing sickness) have you had in your flock this year?.....

d. Has this represented an increase, a decrease or no significant change on numbers of cases of these two diseases from previous years?

.....

e. Have you had any cases of CCN (cerebrocortical necrosis or PEM), or listeriosis, diagnosed in your sheep flock in this or previous years?

.....

f. How many abortions were there in the 1998/1999 lambing season?

.....Was there a diagnosed cause? (Y/N)

What was the cause?.....

g. What major health problems have there been in your flock during the last 12 months?.....

h. Are any organophosphate or pyrethroid products used on your farm (please detail).....

Question 6. a. What type of grazing is provided for lactating ewes? (rough/ permanent/temporary/improved).....

What are the predominant pasture species?.....

.....

b. What feed supplements are provided at grass?.....

.....

c Describe any known soil deficiencies.....

.....

d. What mineral supplements are provided at grass? (Type of mineral, brand of supplement, weight/head in grams).....

.....

e. What fertilisers are applied to pastures (N/P/K/Lime, tonnes/Ha, date of last application)?.....

.....

f. What weed killers/Herbicides/Pesticides are used on the farm?

.....

g. What poisonous plants grow in the sward?.....

h. Are there any infill sites on the farm or local industries (chemical plants, incinerators etc.) near the farm?.....

Question 7. a. Which forages were fed to housed ewes? (Hay, straw, pit silage, bale silage, haylage - give period of feeding and approx. weight in kilos/day)

.....

.....

b. Which concentrates were fed to ewes during housing? (Cereals, distillery by-products, beet pulp, proprietary concentrates - give period of feeding and approx. weight in kilos/day).....

.....

.....

c. What brands of proprietary compounds were used (please include protein percentage if possible).....

.....

d. If home mixes were used, please detail composition, including brand names of any mineral supplements.....
.....

Question 8. a. What type of sward was used to make silage? (Grass, grass/clover, types of grass and clover).....

b. Was any fertiliser used on the sward used to make silage?.....

c. Were there any additives used in the silage? (Bicarb, Sulphate, proprietary).....

d. Were any weed killers used on the sward?.....

e. Were there any poisonous plants in the sward?.....

f. If big bale silage was used, was it home-cut or purchased?
.....

g. Describe the quality of silage fed to the sheep, please compare to previous years.....
.....

APPENDIX 2

CLINICAL EXAMINATION TICK SHEET

DIVISION OF FARM ANIMAL MEDICINE AND PRODUCTION
CLINICAL EXAMINATION SHEET

Case Number: _____ **Clinician:** _____ **Date:** _____

Subjective
Breed: _____ **Sex:** _____ **Age:** _____ **Weight (kg):** _____ **Body Condition Score:** _____

_____
_____
_____

Objective

Temperature: _____ °C / _____ °F

Cardiovascular **Heart Rate (beats/min):** _____

Rhythm	regular		irregular			
pulse volume	normal		poor			
heart sounds	normal		muffled		murmur	
	pericardial sounds					
Percussion	normal		□ ventral thoracic dullness			
venous distension	none		jugular		mammary	
Conjunctivae	normal		pale		congested	
	icteric		cyanotic		petechiae	
oral mm	normal		pale		congested	
	icteric		cyanotic		petechiae	
vaginal mm	normal		pale		congested	
	icteric		cyanotic		petechiae	
Oedema	none		presternal		sub-mandibular	
	limbs		ascites		abdomen wall	
ex. Intolerance	none		present			

Respiratory **Respiratory Rate (breaths/min):** _____

resp. character	normal		hyperpnoea		dyspnoea	
	grunt					
nasal discharge	none		present			
Nose	normal		ulcers		petechiae	
breath odour	normal		halitosis		acetone	
Coughing	none		occasional		frequent	
Auscultation	normal		harshness		squeaks	
	crackles		abnormal URT sounds			
Percussion	normal		□resonance		cough	
	thoracic pain					

Alimentary **Rumen Movements (movements/min):** _____

Appetite	normal		reduced		capricious	
Faeces	normal		scanty		diarrhoea	
Rumination	observed		not observed			
abdomen size	normal		distended		reduced	
rumen tympany	none		present			
tinkle / ping	none		left		right	
abd. Ballotment	normal		pain		foetus	
	fluid		other mass			
Liver	normal		palpable			
Lips	normal		lesions		salivation	
Gums	normal		lesions			
Tongue	normal		lesions			
Cheek	normal		lesions			
hard palate	normal		lesions			

Lymphatic

enlarged LN	none		prescapular		prefemoral	
	sub-mandibular				other	

Female Reproductive

vulva	normal		swollen		ulcers	
	placenta		discharge			
oestrus	cycling		non-cycling			
vagina	normal		ulcers / tear		prolapse	
vag. discharge	none		slight		copious	
	mucous		blood		pus	
udder secretion	none		milk		clots / pus	
MASTITIS	LF		RF		LH	RH
teats	normal		lesions		warts	

Male Reproductive

penis	normal		abnormal	
prepuce	normal		abnormal	
scrotum	normal		abnormal	
testes	normal		abnormal	

Musculoskeletal

skeleton	normal		abnormal			
joints	normal		lesion		pain	
feet	normal		ulcers		pain	
	swollen		overgrown hoof			
gait	normal		abnormal			

Nervous

cranial nn	normal		abnormal	
panniculus	normal		abnormal	
proprioception	normal		abnormal	
CNS signs	normal		abnormal	

Eyes

cornea	normal		abnormal			
discharge	none		present			
vision	normal		impaired			
menace reflex	present		absent			
PMR	present		absent		sluggish	

Ears

ears	normal		abnormal	

Skin

skin	normal		alopecia		lice	
	ringworm		subcutaneous oedema			

Rectal Examination

ovaries	normal		abnormal			
uterus	normal		abnormal		pregnant	
cervix	normal		abnormal			
alimentary	normal		abnormal			
urinary	normal		abnormal			

Assessment _____

Plan _____

_____

Diagnosis _____

APPENDIX 3

NEUROLOGICAL EXAMINATION SHEET

University of Glasgow Veterinary Hospital

Neurological Examination

Date _____

Attach Label Here

Student _____

1) *SUBJECTIVE* .....

.....

.....

2) *OBJECTIVE*

Observation

Mental	Alert		Depressed		Disorientated		Stupor		Coma	
Posture	Normal		Head Tilt		Tremor		Falling			
Gait	Normal		Ataxia		Stiffness		Dysmetria		Circling	
Limbs affected	Pelvic Limbs		Tetra		Hemi		Mono			
Other (e.g. fits)										

Key: **4**=exaggerated, clonus; **3**=increased; **2**=normal; **1**=decreased; **0**=none; **NE**=not evaluated

Weakness

	Left Fore	Right Fore	Left Rear	Right Rear
Hopping				
Wheelbarrow				
Ext. postural thrust				
Hemistand/walk				

Proprioception

	Left Fore	Right Fore	Left Rear	Right Rear
Paw Position				
Reflex Step				
Hip Sway				
Placing-tactile				
Placing-visual				

UMN or LMN

	Left Fore	Right Fore	Left Rear	Right Rear
Muscle Bulk				
Muscle Tone				
Ext. Carpi Rad.				
Patellar				
Pedal				

Panniculus and Sacral Segments

Panniculus	Cut-off		If Yes: Level on L		Level on R	
Anal reflex	Left		Right			
Tail	Voluntary movement					
Bladder	Control		Bladder size		Ease of expression	

Pain

Hyperaesthesia	Cervical		Thoracic		Lumbar		L-Sacral	
Superficial Pain	L-Fore		R-Fore		L-Hind		R-Hind	
Deep Pain	L-Fore		R-Fore		L-Hind		R-Hind	

Cranial Nerves	L	R
Vision 2		
Menace 2,7		
PMR - stim L 2,3		
PMR - stim R 2,3		
Pupil size 2,3,Symp.		
Fundic Exam		
Vest. eye move.		
Strabismus 8,3,4,6		
Nystagmus 8,3,4,6		

	L	R
Facial Sens. *max*		
mandibular		
ophthalmic 5		
Mast. muscle 5		
Facial muscle 7		
Palpebral 5,7		
Gag 9,10		
Tongue 12		
Sympathetic		

Comments CN

Summary of Neurological Exam: .....

.....

.....

3) ASSESSMENT

Location:

		location:
Peripheral NS		
Neuromuscular		
Spinal Cord	C1 to C5	
	C6 to T2	
	T3 to L3	
	L4 to S1	
	S1 to S3	
Brain	Forebrain	
	Brain Stem	
	Vestibular	central? peripheral?
	Cerebellar	
Normal		

Justification for localisation: .....

.....

.....

4) PLAN

Differential Diagnoses:

1. .....
2. .....
3. .....
4. .....
5. .....

Tests:

1. .....
2. .....
3. .....
4. .....
5. .....

APPENDIX 4

TESTING LABORATORIES

Moredun Foundation for Animal Health and Welfare

Pentlands Science Park, Bush Loan, Penicuik, Midlothian, EH26 0PZ (Border Disease Virus)

Scottish Agricultural College Veterinary Science Division

Edinburgh: Bush Estate Penicuik, Midlothian, EH26 0QE (Copper, glutathione peroxidase).

Auchincruive: Auchincruive, Ayre, KA6 5AE (Vitamin B12).

Dumfries: St Mary's Industrial Estate, Dumfries, DG1 1DX (Maedi-visna).

Aberdeen: Mill of Craibstone, Bucksburn, Aberdeen, AB2 9TS (Vitamin E).

University of Glasgow Veterinary School In-House Laboratory

Veterinary Diagnostic Services, University of Glasgow Veterinary School, Bearsden Road, Bearsden, Glasgow G61 1QH

APPENDIX 5

HAEMATOLOGY AND BIOCHEMISTRY RESULTS

Table 4.a. Haematology results from 12 cases of kangaroo gait (UGVS in-house laboratory).

Parameter	Case A	Case B	Case C[α]	Case C[β]	Case D	Case E	Case F	Case H	Case I	Case J	Case K	Case L	Case M	Normal Range
WBC X 10^9/l	7.3	9.4	11.4	7.8	**3.2**	7.4	9.7	4.9	7.8	9.0	11.0	10.0	**12.1**	**4.0 - 12.0**
band X 10^9/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.11**	0.00	0.00	**>0.00**
neut X 10^9/l	3.47	4.51	**7.63**	2.49	1.50	5.25	3.88	3.43	3.82	4.41	5.72	2.80	**7.26**	**0.70 - 6.00**
lymphX 10^9/l	3.65	4.61	3.27	5.18	**1.50**	**1.62**	5.63	**1.12**	3.35	3.60	4.40	6.40	4.48	**2.00 - 9.00**
mono X 10^9/l	0.15	0.19	0.00	0.07	0.06	0.07	0.19	0.09	0.16	0.27	0.22	0.20	0.36	**0.00 - 0.75**
eosin X 10^9/l	0.00	0.09	0.34	0.07	0.12	0.37	0.00	0.19	0.39	0.54	0.33	0.60	0.00	**0.00 - 1.00**
baso X 10^9/l	0.04	0.00	0.17	0.00	0.00	0.07	0.00	0.04	0.08	0.18	0.22	0.00	0.00	**0.00 - 0.30**
RBC X 10^{12}/l	**8.40**	9.14	**7.85**	**8.30**	9.39	9.19	10.86	-	10.40	9.72	9.54	11.90	11.30	**9.00 - 15.00**
Hb g/dl	9.4	9.9	**8.8**	9.2	11.2	10.7	12.4	9.9	11.2	11.7	10.6	13.5	12.4	**9.0 - 15.0**
HT %	**26.3**	27.2	27.9	**25.5**	35.4	33.1	34.6	29.3	31.9	34.1	29.6	38.0	34.1	**27.0 - 45.0**
MCV fl	31.4	29.7	35.5	30.7	37.7	36.0	32.0	32.5	30.7	35.1	31.1	31.9	30.4	**28.0 - 40.0**
MCH pg	11.2	10.9	11.2	11.1	11.9	11.6	11.4	11.0	10.8	12.0	11.1	11.3	11.0	**8.0 - 12.0**
MCHC g/dl	35.6	36.5	31.5	36.1	31.6	32.3	35.8	33.8	35.2	34.2	35.7	35.5	36.2	**31.0 - 38.0**
Retic X 10^9/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**>0.0**
PLT X 10^9/l	296	642	498	**875**	357	**121**	526	379	375	**204**	724	316	553	**250 - 750**

[α] Sample taken 23/4/99
[β] Sample taken 14/5/99

Table 4.B. Biochemistry results from 12 cases of kangaroo gait (UGVS in-house laboratory).

Parameter	Case A	Case B	Case C[α]	Case C[β]	Case D	Case E	Case F	Case H	Case I	Case J	Case K	Case L	Case M	Normal Range
Urea mmol/l	7.1	2.7	2.9	4.4	**11.1**	9.7	7.2	**10.6**	**12.1**	**12.4**	**12.0**	9.3	9.4	**0.0 - 10.0**
Na mmol/l	146	146	144	144	143	**140**	142	145	141	144	144	**139**	**142**	**143 - 151**
K mmol/l	4.7	4.3	4.3	**4.0**	**5.8**	**6.1**	4.3	**6.7**	4.4	**6.5**	5.3	4.7	4.2	**4.1 - 5.6**
Cl mmol/l	108	107	106	108	106	**116**	106	**114**	104	104	108	102	105	**98 - 113**
Ca mmol/l	2.33	**2.29**	**1.82**	**2.12**	**3.10**	2.49	2.34	**2.13**	**2.21**	2.41	2.39	2.60	**2.03**	**2.30 - 2.86**
Mg mmol/l	0.89	0.94	1.16	0.90	0.86	0.80	1.06	0.79	0.79	0.90	0.87	0.91	0.85	**0.78 - 1.32**
IPhos mmol/l	1.48	1.98	2.01	1.75	1.60	1.66	1.28	1.52	1.40	1.44	1.21	1.58	0.97	**0.80 - 2.90**
Creat µmol/l	**165**	**110**	**124**	81	101	104	110	78	80	84	86	**109**	103	**61 - 105**
T. Bili µmol/l	5	1	1	1	1	-	0	1	1	1	-	-	2	**0.0 - 6.0**
AlkP u/l	63	**367**	111	100	437	107	160	68	**294**	**242**	162	**429**	**229**	**0 - 170**
AST u/l	**181**	109	95	131	158	**245**	**168**	112	**153**	**168**	**181**	130	**328**	**0 - 148**
Prot g/l	73	63	61	62.0	74	**84**	74	55	63	74	67	**78**	77	**55 - 77**
Alb g/l	28	30	**22**	**22**	30	**33**	**35**	**22**	29	30	**32**	**35**	29	**24 - 31**
Glob g/l	**45**	33	39	40	44	**51**	39	33	34	**44**	35	**43**	**48**	**30 - 41**
GGT u/l	36	57	49	58	63	41	58	57	45	57	**86**	**73**	**77**	**0 - 60**
GLDH u/l	3	8	5	13	6	-	10	9	**28**	**96**	**62**	9	**65**	**0 - 10**
βHB mmol/l	**1.7**	0.2	0.4	-	0.4	0.3	**0.6**	0.5	**0.6**	**0.6**	**0.7**	0.4	**0.7**	**0.2 - 0.5**
CK u/l	131	250	110	-	**369**	177	183	107	280	**666**	**407**	**537**	**5 181**	**0 - 350**

[α] Sample taken 23/4/99
[β] Sample taken 14/5/99

APPENDIX 6

DEMOGRAPHIC STUDY OF VETERINARY SURGEONS IN NORTHERN BRITAIN: FINAL QUESTIONNAIRE DRAFT

Thank you for your contribution to this study. If you have any further comments to make about kangaroo gait, or if you wish to record any of your thoughts regarding the questions in this document, please use the space below for that purpose.

Do you wish to receive a summary of the results of this study?

1. Yes
2. No

UNIVERSITY
of
GLASGOW

Idiopathic Forelimb Paresis in Sheep (Kangaroo Gait)

A Demographic Study Among Veterinary Surgeons of Northern Britain

Division of Farm Animal Medicine and Production
DEPARTMENT of VETERINARY CLINICAL STUDIES
University of Glasgow Veterinary School
Bearsden Road, Glasgow G61 1QH

Idiopathic forelimb paresis (or Kangaroo Gait) is a clinical syndrome of sheep which presents with some or all of the following signs: a preference for sternal recumbency, knuckling of the joints of the distal forelegs, a bounding gait with leaping propulsive movements of the hind legs, and atrophy of the muscles of the upper forelimbs. The aetiopathogenesis is not clear, though clinical signs are believed to be associated with a selective neuropathy of the radial nerves.

All questions relate to sheep and flocks receiving veterinary care from your <u>current</u> practice only.

Question 1. Approximately what **number of flocks** is provided veterinary care by your practice? _____

Question 2. Approximately what **number of flocks** serviced by your practice is within each of the following size groups.

1. < 50 breeding females _____
2. 50 - 250 breeding females _____
3. 250 - 500 breeding females _____
4. > 500 breeding females _____

Question 14. In your opinion, which of the following statements most correctly describes the economic importance of idiopathic forelimb paresis? (Please circle the adjacent number).

1. This condition is of great importance to the local sheep industry
2. This condition is of moderate importance to the local sheep industry, and of great importance to owners of affected sheep
3. This condition is of low importance to the local sheep industry, and of great or moderate importance to owners of affected sheep
4. This condition is of no importance to the local sheep industry, but it might be of some importance to owners of affected sheep
5. This condition is of no importance to the local sheep industry and is of little importance to owners of affected sheep
6. Unsure

Question 15. Would you be interested in participating in a further, more detailed study of this condition in your local region?

1. Yes
2. No

Question 6. Please indicate if **any** cases of idiopathic forelimb paresis have been examined by (or reported to) you or your colleagues in each of the following types of sheep. (Please circle all adjacent numbers that apply).

1. Adult female sheep
2. Tups/rams (incl. vasectomised)
3. Lambs
4. Adult wethers/castrated males

Question 7. Among cases of idiopathic forelimb paresis in adult female sheep, please indicate if **any** were examined by (or reported to) you or your colleagues, in each of the following physiological states. (Please circle all adjacent numbers that apply).

1. Early pregnancy
2. Late pregnancy (last 8 weeks)
3. Early Lactation (first 4 weeks)
4. Mid/Late Lactation (remainder > 4 weeks)
5. Between weaning and tupping
6. Barren ewes

Question 8. Please list the breeds (or cross breeds) which seem to be most commonly affected with idiopathic forelimb paresis in your practice area. _____

_____

Question 9. Have you or your colleagues examined (or received reports of) **any** cases of idiopathic forelimb paresis from each of the following breed groups? (Please indicate by circling all adjacent numbers that apply).

1. Hill breeds (Blackface, Cheviot, Swaledale etc.)
2. Commercial cross breeds (Mule, Greyface, Half-Bred, Masham)
3. Texels and Texel crosses
4. Suffolk and Suffolk crosses
5. Other native lowland breeds and crosses
6. Other European lowland breeds and crosses
7. Sheep Dairy breeds and crosses

Question 10. Among flocks in your practice area in which one or more cases of idiopathic forelimb paresis have been examined or reported, approximately what **number of flocks** is **predominantly** managed under each of the following production systems?

1. Lowland Farms _____
2. Upland Farms _____
3. Hill Farms _____
4. Others (please specify)_____ _____

Question 11. In which year did you first examine or receive a report of a case of idiopathic forelimb paresis?

19_____

Question 12. In approximately what **number of flocks** in your practice area have cases of idiopathic forelimb paresis been reported or examined in each of the following time periods?

1. 1999 _____
2. 1998 _____
3. 1997 _____
4. 1990 - 1996 (Total number) _____
5. Before 1990 (Total number) _____

Question 13. Among flocks in your practice area in which one or more cases of idiopathic forelimb paresis have been reported or examined, approximately **what percentage of the flock** (on average) has been affected in any one year? (Please circle the most correct response).

1. < 0.2 % (less than 1 per 500 adult sheep)
2. 0.2 - 0.5 % (1 per 200 - 500 adult sheep)
3. 0.5 - 1.0 % (1 per 100 - 200 adult sheep)
4. 1.0 - 2.0 % (1 per 50 - 100 adult sheep)
5. 2.0 - 5.0 % (1 per 20 - 50 adult sheep)
6. > 5.0 % (more than 1 per 20 adult sheep)

Question 3. Approximately what **number of flocks** receiving veterinary care from your current practice are **predominantly** managed under each of the following production systems?

1. Lowland farming _____
2. Upland farming _____
3. Hill farming _____
4. Other (please specify)_____ _____

Question 4. Do you recall **examining** any cases of idiopathic forelimb paresis in sheep fitting the above description? (Please **circle the number** adjacent the correct response).

1. Yes.....please proceed to Q 6.
2. No.....please proceed to Q 5.

Question 5. Do you recall receiving verbal (or written) **reports** of idiopathic forelimb paresis in sheep from your sheep owning clients? (Please circle the number adjacent the correct response).

1. Yes.....please proceed to Q 6.
2. No.....please proceed to Q 14.

APPENDIX 7

DEMOGRAPHIC STUDY OF VETERINARY SURGEONS OF NORTHERN BRITAIN: COVERING LETTER

«Vet
«Practice
«Street1
«Street2
«TOWN
«COUNTY
«Postcode

UNIVERSITY
of
GLASGOW

9 August 1999

Dear

Over the last two lambing seasons, we at the University of Glasgow Veterinary School have seen an increasing number of cases of an unusual forelimb problem, affecting ewes in late pregnancy and/or lactation. The clinical presentation of bilateral forelimb paresis is described in the veterinary literature as 'Kangaroo Gait'. Publications have concentrated on clinical and pathological investigations of small numbers of cases, though little is known about the aetiology or epidemiology of this condition. Importantly, there is no information on the economic significance or prevalence of Kangaroo Gait. This lack of information has prompted us to initiate a questionnaire study among veterinary practitioners covering the area from which our referred cases have come.

Your practice has been randomly selected from a list taken from The Register of Veterinary Practices, which covers the geographical area of interest. We would be very grateful if you could find the time to complete and return the enclosed questionnaire (a stamped, addressed envelope is provided), even if your practice no longer provides veterinary care for sheep, or if you have never seen cases or heard of this condition. If there is another veterinary surgeon in your practice who you feel is better placed to complete the questionnaire on behalf of your practice, please pass the questionnaire on to that person. You may be assured that the responses provided will be treated with complete confidentiality.

The results of this study will contribute valuable demographic information to our knowledge of this condition. Depending upon the results of this study, we anticipate that more detailed epidemiological, clinical and pathological research into Kangaroo Gait will be conducted in the future. A section on the last page of the questionnaire asks you to indicate whether you would be willing to participate in more detailed future studies. Should you have any questions regarding the enclosed questionnaire, please do not hesitate to contact me by mail, telephone or email. Thank you for your time; we look forward to receiving your completed questionnaire in the near future.

Yours faithfully

Archie Clements BVSc (Hons) MRCVS

DIVISION OF FARM ANIMAL MEDICINE AND PRODUCTION
DEPARTMENT of VETERINARY CLINICAL STUDIES
University of Glasgow Veterinary School
Bearsden Road, Glasgow G61 1QH
Telephone: 0141-330-5700 *Fax:* 0141-942-7215 *Email:* acc11d@udcf.gla.ac.uk

APPENDIX 8

DEMOGRAPHIC STUDY OF VETERINARY SURGEONS OF NORTHERN BRITAIN: FIRST (POSTCARD) REMINDER

FRONT SIDE:

Idiopathic Forelimb Paresis (Kangaroo Gait):
A Study Among Veterinary Surgeons of Northern Britain

UNIVERSITY
of
GLASGOW

Division of Farm Animal Medicine and Production
DEPT. VETERINARY CLINICAL STUDIES.
University of Glasgow Veterinary School
Bearsden Road, Glasgow G61 1QH

REAR SIDE:

Dear 16 August 1999

Last week a questionnaire seeking information regarding an unusual forelimb problem of sheep was mailed to you, your practice having been randomly selected from The Register of Veterinary Practices.

If you have already completed the questionnaire and returned it to us, please accept our sincere thanks. If not, we would be most grateful if you could find the time to do so. If by some chance, you did not receive the questionnaire or have misplaced it, please ring the secretary of the Division of Farm Animal Medicine and Production at the University of Glasgow on 0141 330 5721 and we will post a replacement today. Thank you for your time.

Yours faithfully

Archie Clements BVSc (Hons) MRCVS

APPENDIX 9

DEMOGRAPHIC STUDY OF VETERINARY SURGEONS OF NORTHERN BRITAIN: SECOND REMINDER LETTER

UNIVERSITY
of
GLASGOW

«Vet
«Practice
«Street1
«Street2
«TOWN
«COUNTY
«Postcode

9 August 1999

Dear

About six weeks ago I posted a questionnaire to you, seeking information regarding an unusual forelimb problem of sheep, described in the veterinary literature as 'Kangaroo Gait'. Your practice was randomly selected from those recorded in The Register of Veterinary Practices as providers of veterinary care for sheep. As yet we have not received your completed questionnaire.

This study was initiated in order to gain valuable demographic information about Kangaroo Gait, in order to estimate the importance of this condition, both to local economies and to the welfare of affected individuals. The response so far has been high, but in order to ensure that the information gained is representative, it is equally important that questionnaires are returned from practices which have not seen cases of Kangaroo Gait, as it is from those that have seen cases. It is also important that we receive questionnaires from practices that no longer provide veterinary care for sheep.

A replacement copy of the questionnaire is provided in case your original has been misplaced, and a second stamped, addressed envelope is also provided. Once again we ask that if there is another veterinary surgeon in your practice who you feel is better placed to complete the questionnaire on behalf of your practice, please pass the questionnaire on to that person. You may be assured that the responses provided will be treated with complete confidentiality. Thank you for taking the time to complete and return this questionnaire.

Yours faithfully

Archie Clements BVSc (Hons) MRCVS

DIVISION OF FARM ANIMAL MEDICINE AND PRODUCTION
DEPARTMENT of VETERINARY CLINICAL STUDIES
University of Glasgow Veterinary School
Bearsden Road, Glasgow G61 1QH
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APPENDIX 10

DEMOGRAPHIC STUDY AMONG SHEEP FLOCK OWNERS AND MANAGERS OF THE SCOTTISH BORDERS: FINAL QUESTIONNAIRE DRAFT

UNIVERSITY
of
GLASGOW

Locomotor Disorders of Sheep

A Study Among Sheep Flock Owners and Managers of The Scottish Borders

Division of Farm Animal Medicine and Production
DEPARTMENT of VETERINARY CLINICAL STUDIES
University of Glasgow Veterinary School
Bearsden Road, Glasgow G61 1QH

Section 1. Farm Details

Question 1. How many of the following types of sheep do you have?

1. Adult tups _____
2. Adult ewes _____
3. Gimmers _____
4. This season's lambs (winter 1999/2000) _____
5. Others (please specify)_____ _____

Question 2. How many adult breeding female sheep of each breed or cross breed do you have?

1. Breed or cross_____ Number_____
2. Breed or cross_____ Number_____
3. Breed or cross_____ Number_____
4. Breed or cross_____ Number_____

Question 3. Please indicate what type of sheep enterprises you have on your farm (Please circle all numbers that apply).

1. Commercial fat lamb production
2. Commercial breeding stock production
3. Pedigree breeding stock production
4. Other (please specify)_____

Question 4. How many hectares of your farm's area are grazed by sheep, in each of the following categories?

1. Lowland grazing _____
2. Upland grazing _____
3. Hill grazing _____

Question 5. What date did lambing commence in the 1998/1999 season? (If you have two or more separate flocks, please consider the largest flock only). _____/_____/_____

Question 6. How many weeks long was the lambing period (i.e. over 95% of ewes lambed)?

_____

Question 7. On what date were the majority of lambs weaned in 1999 (Day/Month)?

_____/_____/1999

Question 8. If sheep were housed 24 hours per day during the 1998/1999 winter, between what dates were the majority of your flock housed (Day/Month)?

Question 9. If sheep were partly housed (e.g. at night) and partly at grass (e.g. during the day) during the 1998/1999 winter, between what dates were the majority of your flock housed (Day/Month)?

From__/_____To____/_____

Question 10. What is the postcode of your farm? _____

Section 2. Flock Health Details

Question 11. Please circle numbers adjacent any of the following schemes by which your flock is accredited or monitored.

1. Enzootic Abortion of Ewes (E. A. E.) accreditation scheme
2. Maedi-Visna accreditation scheme
3. Maedi-Visna monitoring scheme
4. Scrapie monitoring scheme

Question 12. Do you have a written flock health plan, containing details of lameness treatment and prevention (Please circle the number adjacent the correct response)?

1. Yes
2. No

Question 13. Approximately how many visits have you had to your sheep flock in 1999 from your veterinarian? _____

Question 14 Does this number represent an increase, a decrease or no significant change in the annual number of visits during the previous five years? _____

Question 15. Which of the following statements best describes the likelihood that you would contact your vet for a diseased sheep in 1999 compared to the previous five years? (Please circle the number adjacent the most correct response)

1. Less likely
2. Just as likely
3. More likely

Question 16. Did you vaccinate your sheep for footrot in 1999?

1. Yes
2. No

Question 17. Do you keep antibiotics (injectable or sprays) on farm to treat cases of footrot or other causes of lameness?

1. Yes.....Which Antibiotic(s)? _____
2. No

Question 18. Please estimate numbers of animals affected with the following disorders among each class of sheep described below, i) for which you requested veterinary attention to your flock **in 1999**, and ii) which occurred in your flock **in 1999** but for which you did not seek veterinary attention.

Presenting Condition	**Veterinary Attention Requested**	**No Veterinary Attention Requested**
1. Diseases of the skin **between the cleats**. e.g. scald, footrot, interdigital fibromas (growths)	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
2. Foot diseases with damage to the **hoof wall** or **abscessation** (pus). e.g. toe abscesses, hoof abscesses, soil balling, white line disease, toe granulomas, laminitis	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
3. Swelling and pain of **joints**. e.g. joint ill, arthritis.	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
4. Lameness of **all four limbs** causing a shuffling, stilted or shaky stride. e.g. neck injuries in fighting tups, louping ill, listeriosis, border disease.	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
5. **Weakness** of **both front limbs** causing kneeling or lying down, knuckling of the front limbs, a bounding motion. e.g. Kangaroo Gait (see Section 3)	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
6. **Weakness** of **both hindlimbs** causing swaying, knuckling or dragging of hind limbs. e.g. spinal abscessation, swayback, lambing damage of ewes, scrapie.	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
7. Lameness associated with painful lesions of the **skin or udder**. e.g. strawberry footrot, severe mastitis (blue bag)	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
8. Abnormal walking motion associated with abnormal **conformation** of the limbs. e.g. tendon contracture, rickets	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings_____
9. Lameness of one or more limbs due to **trauma.** e g broken limbs, sprains, bruising	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings	Adult Tups _____ Ewes/Gimmers _____ Lambs/Shearlings

Question 19. Please rank the following in decreasing order of importance (1. most important - 8. least important) when considering whether or not you would request veterinary attention for a diseased sheep.

Rank:

1. Degree of pain/ discomfort experienced by the sheep. _____

2. Financial considerations, i.e. the cost of losing the sheep/decreased productivity of the sheep compared to the cost of the veterinary visit. _____

3. Your level of confidence that you can diagnose and treat the condition without veterinary assistance. _____

4. Cost in labour and time required to look after the sheep if treatment is required. _____

5. Concern that other sheep will become affected if veterinary attention is not sought. _____

6. Likelihood of the vet being able to find a cure or increase the productivity of the sheep. _____

7. What other farmers or members of the public may think or say if they see a diseased sheep on your farm. _____

8. Any other factors (please specify)_____ _____

Section 3. Kangaroo Gait

Kangaroo Gait (or Kangaroo Disease) is a condition of sheep with signs which include;

1. A preference for lying down (in a normal position).

2. Standing with front legs stretched forward, and hind legs under the body taking most of the weight.

3. A bounding step due to leaping propulsive movements of the hind legs.

4. Front leg weakness, resulting in the animal frequently falling onto the knees.

Affected animals are usually alert and have a good appetite.

Question 20. Have you ever had any cases of Kangaroo Gait diagnosed in your sheep following examination by your vet (please circle the number adjacent the correct response)?

1. Yes
2. No

Question 21. In what year was the first case diagnosed? 19_____

Question 22. Have you had any sheep in your flock with signs which resembled the above description of Kangaroo Gait, but which your vet did not examine (please circle the number adjacent the correct response)?

1. Yes
2. No

Question 23. How many adult female sheep would have to develop the signs described above before you would request assistance from your veterinarian? _____

If you answered 'No' to Q's 20 and 22 please proceed to Section 4. If the answer to either of these Q's was 'yes', please proceed to Q 25.

Question 24. Please list the breeds/cross breeds of sheep in which this condition has occurred._____

_____

Question 25. How many sheep in your flock developed Kangaroo Gait in each of the following time periods?

1. 1999 _____
2. 1998 _____
3. 1997 _____
4. 1990-1996 (Total number) _____
5. Before 1990 (Total number) _____

Question 26. Have any sheep developed Kangaroo Gait in two or more years?

1. Yes
2. No
3. Unsure

Question 27. Please circle the month(s) of the year during which cases of Kangaroo Gait have initially occurred (i.e. the months during which signs first occurred)?

1. January
2. February
3. March
4. April
5. May
6. June
7. July
8. August
9. September
10. October
11. November
12. December

Question 28. Have any sheep developed Kangaroo Gait while kept under each of the following systems (please circle all numbers that apply)?

1. At grass
2. Housed 24 hours/day
3. Housed temporarily (at grass during part or all of the day)

Question 29. Please indicate if **any** cases of Kangaroo Gait have occurred in your flock in each of the following types of sheep (Please circle all adjacent numbers that apply).

1. Ewes
2. Gimmers
3. Tups/rams (including vasectomised)
4. Lambs
5. Other (please specify) _____

Question 30. Have any **adult female sheep** which developed Kangaroo Gait gone on to the following outcomes (Please circle all numbers that apply)?

1. Recovery while nursing lambs
2. Recovery while not nursing lambs or after weaning of lambs
3. Death (not due to euthanasia/culling)
4. Euthanasia
5. Sold or moved off farm before the outcome was known

Question 31. Among **adult female sheep** which developed Kangaroo Gait, please indicate if **any** initially occurred during the following stages (Please circle all adjacent numbers that apply).

1. Early pregnancy
2. Late pregnancy (last 8 weeks)
3. Early Lactation (first 4 weeks)
4. Mid/Late Lactation (remainder > 4 weeks)
5. After weaning and before tupping
6. Non-reproductive (barren ewes, maiden ewes, unmated ewes)

Question 32. Among **adult female sheep** which developed Kangaroo Gait, please indicate if **any** were suckling the following numbers of lambs (Please circle all adjacent numbers that apply).

1. Single
2. Two
3. Three or more

Question 33. If more than one sheep developed Kangaroo Gait in any one year, did they normally develop the condition:

1. Within 24 hours of each other
2. Within 7 days of each other
3. Within one month of each other
4. Over a period greater than one month

Question 34. Which of the following statements best describes the economic importance of Kangaroo Gait in your flock

1. Very important
2. Moderately important
3. Not very important

Section 4.

Thank you for your contribution to this study. If you have any further comments to make about Kangaroo Gait, or if you wish to record any of your thoughts regarding the questions in this document, please use the space below for that purpose.

If you wish to receive a summary of the results of this study please provide your contact details below.

Title_____ Your name_____

Address_____

_____

Fax

APPENDIX 11

DEMOGRAPHIC STUDY AMONG SHEEP FLOCK OWNERS AND MANAGERS OF THE SCOTTISH BORDERS: COVERING LETTER

UNIVERSITY
of
GLASGOW

4 February 2000

Dear Sir/Madam

During the last two lambing seasons we, at the University of Glasgow Veterinary School, have seen an increase in the number of cases of an unusual problem affecting the front legs of ewes in late pregnancy and/or lactation. Ewes are seen with weakness and knuckling of the front legs, leading to an abnormal bounding (or bunny-hopping) stride. This condition has been called 'Kangaroo Gait'. Little is known about how, or why, sheep develop this condition. We do not know how many sheep suffer from this condition each year, nor is there any information about how economically important Kangaroo Gait is. This lack of information prompted us to initiate a questionnaire study among veterinary practices in Northern Britain. The response to this questionnaire has been very good, and valuable information has been obtained regarding the distribution and nature of the cases of this condition which have been reported to vets.

However, we are confronted with the problem that veterinary surgeons often do not have access to detailed information about individual sheep or the flocks from which cases come. In addition, we believe that an unknown proportion of cases are not reported to vets. In order to gain more accurate information, we wish to initiate a follow-up survey of sheep flock owners. The aim of this second study is to provide more detailed information regarding Kangaroo Gait, as well as other conditions which affect the locomotion (movement) of sheep, termed 'locomotor disorders'. As a flock owner or manager, only you can provide this information.

Your veterinary surgeon has kindly agreed to participate in this survey by distributing questionnaires to flock owners in your area. We would be very grateful if you could find the time to complete and return the questionnaire (a stamped, addressed envelope is provided), even if you have never seen cases of Kangaroo Gait or if you have never heard of this condition. **The responses provided will be treated with complete confidentiality.** The identity of flocks or flock owners participating in this survey will not be revealed to any 3rd party and only summarised results for the survey area as a whole will be presented in any reports arising from this work.

The results of this study will contribute valuable information to our knowledge of diseases of locomotion in sheep. Should you have any questions regarding the enclosed questionnaire, please do not hesitate to contact me by mail or telephone (contact details can be found at the foot of this page). Thank you for your time, we look forward to receiving your completed questionnaire in the near future.

Yours faithfully

Archie Clements BVSc (Hons) MRCVS

DIVISION OF FARM ANIMAL MEDICINE AND PRODUCTION
DEPARTMENT of VETERINARY CLINICAL STUDIES
University of Glasgow Veterinary School
Bearsden Road, Glasgow G61 1QH
Telephone: 0141-330-5700 *Fax:* 0141-942-7215 *Email:* acc11d@udcf.gla.ac.uk

APPENDIX 12

DEMOGRAPHIC STUDY AMONG SHEEP FLOCK OWNERS AND MANAGERS OF THE SCOTTISH BORDERS: POSTCARD REMINDER

FRONT SIDE:

Locomotor Disorders of Sheep
A Study Among Sheep Flock Owners and Managers of the Scottish Borders

UNIVERSITY
of
GLASGOW

Division of Farm Animal Medicine and Production
DEPT. VETERINARY CLINICAL STUDIES.
University of Glasgow Veterinary School
Bearsden Road, Glasgow G61 1QH

REAR SIDE:

Dear Sir/Madam 6 March 2000

Last month a questionnaire seeking information regarding locomotor disorders of sheep, including 'Kangaroo Gait', was mailed to you by your veterinary surgeon. So far the response rate has been good, however to ensure the results of the survey are accurate we need to receive more completed questionnaires.

If you have already completed the questionnaire and returned it to us, please accept our sincere thanks. If not, we would be most grateful if you could find the time to do so. If by some chance, you did not receive the questionnaire or have misplaced it, please ring me at the University of Glasgow on 0141 330 5700 and I will post a replacement today. Thank you for your time.

Yours faithfully

Archie Clements BVSc (Hons) MRCVS

APPENDIX 13

NUMBERS OF SHEEP AFFECTED WITH VARIOUS CATEGORIES OF LOCOMOTOR DISORDER FOR WHICH VETERINARY ATTENTION WAS AND WAS NOT SOUGHT IN 1999: TABLES OF DESCRIPTIVE STATISTICS

Table 1. Cases with interdigital lesions.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0.02	1.28	0.26	5.07	55.29	28.97
Standard Error	0.02	1.12	0.26	0.51	9.17	8.93
Median	0	0	0	3	20	10
Mode	0	0	0	2	20	0
Std. Deviation	0.18	12.14	2.77	5.49	98.77	96.15
Range	2	130	30	30	600	1000
Minimum	0	0	0	0	0	0
Maximum	2	130	30	30	600	1000
Sum	2	150	30	593	6414	3361
Count	117	117	117	117	116	116

Table 2. Cases with lesions of the hoof wall or internal hoof structures.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0.02	0.17	0	1.50	10.51	4.66
Standard Error	0.01	0.17	0	0.24	2.52	1.87
Median	0	0	0	0	5	0
Mode	0	0	0	0	0	0
Std. Deviation	0.13	1.85	0	2.64	27.03	20.10
Range	1	20	0	15	200	200
Minimum	0	0	0	0	0	0
Maximum	1	20	0	15	200	200
Sum	2	20	0	175	1209	541
Count	117	117	117	117	115	116

Table 3. Cases with painful lesions of the joints.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0.02	0	0.71	0.28	0.91	5.68
Standard Error	0.01	0	0.33	0.07	0.28	1.43
Median	0	0	0	0	0	0
Mode	0	0	0	0	0	0
Std. Deviation	0.13	0	3.61	0.76	3.08	15.48
Range	1	0	31	5	30	150
Minimum	0	0	0	0	0	0
Maximum	1	0	31	5	30	150
Sum	2	0	83	33	107	665
Count	117	117	117	117	117	117

Table 4. Cases with abnormal locomotion of all four limbs.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0.02	0.01	0.03	0.05	0.67	0.44
Standard Error	0.01	0.01	0.03	0.02	0.29	0.16
Median	0	0	0	0	0	0
Mode	0	0	0	0	0	0
Std. Deviation	0.13	0.09	0.34	0.26	3.12	1.76
Range	1	1	4	2	30	11
Minimum	0	0	0	0	0	0
Maximum	1	1	4	2	30	11
Sum	2	1	4	6	78	52
Count	117	117	117	117	117	117

Table 5. Cases with weakness of the front limbs.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0	0.04	0	0.03	0.41	0.15
Standard Error	0	0.03	0	0.02	0.10	0.10
Median	0	0	0	0	0	0
Mode	0	0	0	0	0	0
Std. Deviation	0	0.33	0	0.22	1.10	1.08
Range	0	3	0	2	6	10
Minimum	0	0	0	0	0	0
Maximum	0	3	0	2	6	10
Sum	0	5	0	4	48	18
Count	117	117	117	117	117	117

Table 6. Cases with weakness of the hind limbs.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0.01	0.04	0.01	0.01	0.18	0.52
Standard Error	0.01	0.04	0.01	0.01	0.06	0.12
Median	0	0	0	0	0	0
Mode	0	0	0	0	0	0
Std. Deviation	0.09	0.46	0.09	0.09	0.61	1.30
Range	1	5	1	1	4	10
Minimum	0	0	0	0	0	0
Maximum	1	5	1	1	4	10
Sum	1	5	1	1	21	61
Count	117	117	117	117	117	117

Table 7. Cases with painful lesions of the skin or udder.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0	0.04	0	0.14	3.71	0.15
Standard Error	0	0.04	0	0.06	0.42	0.09
Median	0	0	0	0	2	0
Mode	0	0	0	0	0	0
Std. Deviation	0	0.38	0	0.61	4.57	0.99
Range	0	4	0	5	20	10
Minimum	0	0	0	0	0	0
Maximum	0	4	0	5	20	10
Sum	0	5	0	16	434	18
Count	117	117	117	117	117	117

Table 8. Cases with abnormal conformation.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0	0.03	0	0	0.13	0.34
Standard Error	0	0.03	0	0	0.04	0.09
Median	0	0	0	0	0	0
Mode	0	0	0	0	0	0
Std. Deviation	0	0.28	0	0	0.46	0.97
Range	0	3	0	0	2	6
Minimum	0	0	0	0	0	0
Maximum	0	3	0	0	2	6
Sum	0	3	0	0	15	40
Count	117	117	117	117	117	117

Table 9. Cases caused by trauma.

Descriptive Statistic	Veterinary Attention Sought			No Veterinary Attention		
	Tups	Ewes	Lambs	Tups	Ewes	Lambs
Mean	0	0	0.03	0.10	0.54	0.98
Standard Error	0	0	0.03	0.03	0.13	0.13
Median	0	0	0	0	0	0
Mode	0	0	0	0	0	0
Std. Deviation	0	0	0.29	0.33	1.42	1.45
Range	0	0	3	2	10	8
Minimum	0	0	0	0	0	0
Maximum	0	0	3	2	10	8
Sum	0	0	4	12	63	115
Count	117	117	117	117	117	117

GLOSSARY OF TERMS

AETIOLOGY	The cause of a disease.
ANAMNESIS	The history of a patient.
BARREN EWE	A ewe that is unable to conceive or produce viable offspring.
BEEF SUCKLER HERD	A herd of cattle consisting of dams and young calves up to the age of weaning.
CAST EWE	A ewe that is culled or selected to be culled from the flock.
EWE	An adult female sheep of breeding age.
EWE HOGG	A female sheep in it's second year.
FETLOCK	The metacarpo- or metatarso- phalyngeal joint.
GIMMER	A female sheep in its' third year.
HILL PASTURE	High altitude, often steep, unimproved grassland pasture, grazed with a low stocking density.
LOWLAND PASTURE	Low altitude, flat or undulating, usually improved pasture, grazed at a high stocking density.
PERMANENT GRAZING	A grazing system where the flock is kept in a single field without rotation.
PERMANENT PASTURE	Pasture that is managed under a permanent grazing system.
PHYTOTOXICITY	A toxicity of plant origin.
ROTATIONAL GRAZING	A grazing system where the flock is moved from field to field throughout the grazing season.
STORE LAMB	A growing lamb in lean body condition that requires good quality pasture to attain a size and weight suitable for slaughter.
SWARD	The herbage (grasses and legumes) that comprises an area of pasture.
TACHYPNOEA	Abnormally rapid breathing.
TEASER RAM	A male sheep that is infertile or unable to mate, that is used to sexually stimulate female sheep.
TUP	An adult entire male sheep that has reached sexual maturity.

TUP HOGG	An entire male sheep in its' second year.
TUPPING	The mating of a male and a female sheep.
UPLAND PASTURE	Intermediate altitude, often improved pasture grazed with a medium stocking density.
WETHER	A castrated male sheep.

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