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The Arthropod and Helminth Parasites of Red Deer (*Cervus elaphus* L.) in New Zealand.*

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Abstract

FIFTEEN parasites of forty red deer (*Cervus elaphus* L.) from New Zealand are recorded. The ectoparasites are: *Damalinia longicornis* (Nitzsch), *Solenopotes burmeisteri* (Fahrenholz)—Phthiraptera, and *Haemaphysalis bispinosa* Neumann—Acarina. The endoparasites are: *Ostertagia leptospicularis* Assadov, *Ostertagia rubricervi* Andrews, *Rinadia quadrifurcata* Andrews, *Apteragia quadrispiculata* Jansen, *Spiculopteragia asymmetrica* (Ware), *S. böhmi* (Gebauer), *Capillaria bovis* (Schnyder), *Dictyocaulus viviparus* (Bloch), *Oesophagostomum venulosum* (Rudolphi), *Trichuris ovis* (Abildgaard), — Nematoda; *Fasciola hepatica* L. — Trematoda; *Taenia hydatigena* Pallas = (*Cysticercus tenuicollis* Rudolphi) — Cestoda. A key to the helminth parasites is given.

The red deer acts as a reservoir host for the parasites of domestic stock; ***Fasciola hepatica, Cysticercus tenuicollis*** and ***Dictyocaulus viviparus,*** causing death in stock and economic loss, and *Haemaphysalis bispinosa* causing severe irritation in cattle and other farm animals. There is some similarity between the parasitic fauna of red deer in other countries and that found in the present study. The overall effect of the parasitic fauna upon red deer in New Zealand is considered to be slight.

* This paper is part of a study on the parasites of red deer, presented for M.Sc. thesis at the Victoria University of Wellington.

INTRODUCTION

THE red deer (*Cervus elaphus* L.) has been present in New Zealand for a period of more than one hundred years. During this time it has achieved a wide distribution, its range often bordering on, or overlapping the farmland occupied by sheep, cattle, and other domestic animals. The red deer population has grown steadily over the years, gaining a noteworthy place in New Zealand's land economy as a causal agent of erosion in many important water catchment areas. Because of the ability of red deer to eat and rapidly destroy vegetation, flood danger in many lowland areas has increased, creating many conservational and economic problems. To counteract this population growth extensive control measures have been put into operation, taking the form of shooting and, more recently, poisoning.

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Over the years a small internal and export trade has been built up for the meat and skins of this animal, and further consideration is now being given to the meat export potential of red deer. Their firm establishment as animals of significance amongst New Zealand's introduced mammals has led to considerable research to evaluate their relationships to vegetation, erosion, and other introduced feral mammals.

As New Zealand's economy is largely dependent on farm animal production, special note has been taken in this work, of the ability of red deer to act as a reservoir host for parasites of sheep, cattle and other domestic animals.

This work, involving both endoparasites and ectoparasites, has resulted in the description of specimens from many taxa in the animal kingdom. The parasites recovered have included representatives from the following groups: Phylum Platyhelminthes (Class Cestoda, Class Trematoda); Phylum Aschelminthes (Class Nematoda); Phylum Arthropoda (Class Insecta, Class Arachnida). Of seventeen parasites described, two are new species, two have been described from red deer for the first time, and five have not been recorded previously as occurring in New Zealand.

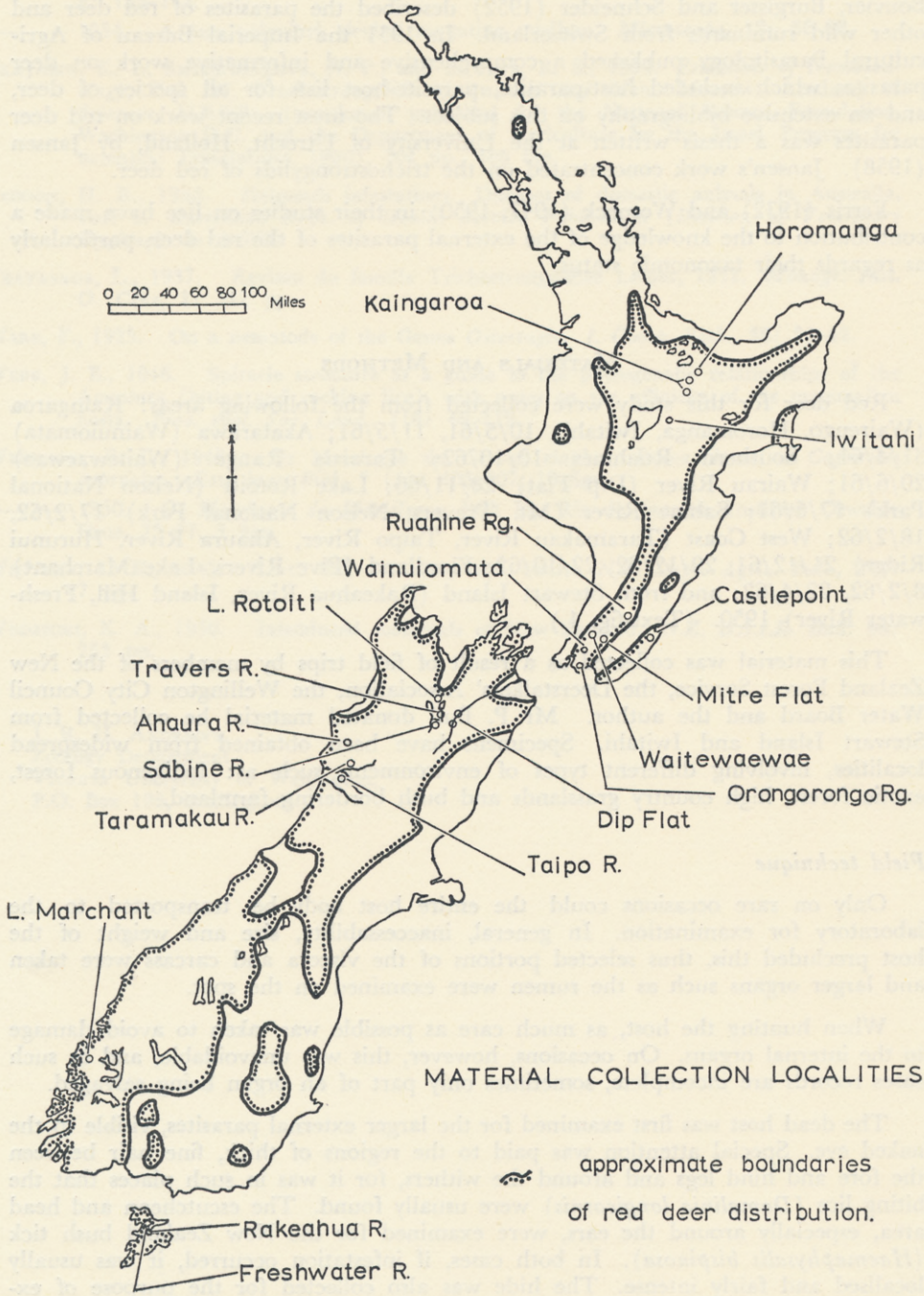
I would like to thank Mr R. Forsyth, Mr H. Maunder, and others who helped in the collection of material, and also members of the Zoology Department, Victoria University of Wellington, who assisted in the preparation of this paper.

HISTORICAL

Red deer were liberated in New Zealand more than one hundred years ago, in the Matai Valley, near Nelson. Following this a liberation was made in the North Island in 1862, at the Taratahi Plains, Carterton. Subsequently, numerous successful liberations were made in both the North and South Islands and Stewart Island, more than one hundred liberations being known from 1851 to 1923 (Wodzicki, 1950). Following these liberations the red deer thrived and spread to occupy the central and southern parts of the North Island, almost the whole of the South Island (excluding parts of Canterbury), and Stewart Island. They are, for the most part, restricted to the high country and areas of indigenous bush, but are known to inhabit the exotic forests and in some cases farms, where the farmland borders on native bush or is part of a high country area.

The deer herds from which these liberations were made were predominantly English and Scottish, although about six liberations were made with animals from Australian deer parks, but the latter were originally from English or Scottish herds. Later, liberations were made in the North Island from stock in the South Island and vice versa.

The first record of a parasite from red deer was made by Redi (1668) who described an external parasite that is now known as *Damalinia longicornis*. From the end of the seventeenth century to the beginning of the twentieth century, little work was done in this field. Then Brumpt (1911) made a study of the parasites of a small herd of deer from France. Some members of this herd had died mysteriously, and Brumpt in his subsequent investigations found present in the dead hosts the lungworm of deer, *Dictyocaulus noerneri* (= *D. viviparus*) *Capillaria* sp. and *Oesophagostomum venulosum*. Next in the field was Cameron (1931) who did extensive work on the parasites of red deer from Scotland, recording some eleven species of nematodes. Among these were the lungworm *Dictyocaulus viviparus, Skrjabinagia cervi*, a small trichostrongylid peculiar to the red deer, *Nematodirus* sp., an intestinal parasite of lambs, *Chabertia ovina*,



TEXT-FIG. 1.—Map showing localities from which material was collected, and distribution of red deer in New Zealand.

and *Monezia expansa*, the sheep tapeworm. In the next major work in this field, Bouvier, Burgisser and Schneider (1952) described the parasites of red deer and other wild ruminants from Switzerland. In 1931 the Imperial Bureau of Agricultural Parasitology published a comprehensive and informative work on deer parasites which included host-parasite, parasite-host lists for all species of deer, and an extensive bibliography on this subject. The most recent work on red deer parasites was a thesis written at the University of Utrecht, Holland, by Jansen (1958). Jansen's work concentrated on the trichostrongylids of red deer.

Ferris (1932) and Werneck (1947, 1950) in their studies on lice have made a contribution to the knowledge of the external parasites of the red deer, particularly as regards their taxonomic status.

Materials and Methods

Red deer for this study were collected from the following areas: Kaingaroa (Wairengo, Horomanga, Iwitahi) 10/5/61, 11/5/61; Akatarawa (Wainuiomata) 31/4/61; Southern Ruahines 10/10/62; Tararua Range (Waitewaewae) 20/6/61; Wairau River (Dip Flat) 28/11/60; Lake Rotoiti (Nelson National Park) 17/6/61; Sabine River (Mt. Travers, Nelson National Park) 17/2/62, 18/2/62; West Coast (Taramakau River, Taipo River, Ahaura River, Hurunui Ridge) 21/12/61, 20/12/62, 22/10/62; Fiordland (Five Rivers, Lake Marchant) 8/2/62, 22/4/62; and from Stewart Island (Rakeahua River, Island Hill, Freshwater River) 1950. (Text-fig. 1.)

This material was collected as a result of field trips by members of the New Zealand Forest Service, the Deerstalkers' Association, the Wellington City Council Water Board and the author. Mr P. Bull donated material he collected from Stewart Island and Iwitahi. Specimens have been obtained from widespread localities, involving different types of environment, such as: indigenous forest, exotic forest, high country grasslands and bush bordering farmland.

Field technique

Only on rare occasions could the entire host body be transported to the laboratory for examination. In general, inaccessability, size and weight of the host precluded this, thus selected portions of the viscera and carcass were taken and larger organs such as the rumen were examined on the spot.

When hunting the host, as much care as possible was taken to avoid damage to the internal organs. On occasions, however, this was unavoidable, and in such cases records are incomplete, sometimes only part of an organ being salvaged.

The dead host was first examined for the larger external parasites, visible to the naked eye. Special attention was paid to the regions of thick, fine hair between the fore and hind legs and around the withers, for it was in such places that the biting lice (*Damalinia longicornis*) were usually found. The escutcheon and head area, especially around the ears, were examined for the New Zealand bush tick (*Haemaphysalis bispinosa*). In both cases, if infestation occurred, it was usually localised and fairly intense. The hide was also collected for the purpose of examination for mites and ticks not clearly visible to the naked eye. The infected skin was removed, rolled up, fur side inwards, and placed in a plastic bag. It was found that the ectoparasites rarely detached themselves from the skin of the host, remaining entangled in the hair until removal in the laboratory.

Next the nostril and ear cavities of the host were examined for Diptera larvae. The host was then examined for endoparasites. A ventral incision from the pelvic symphysis to the diaphragm was made, the flaps of the body wall reflected, and the entire viscera including the lungs and liver removed. The rumen was cut open and the contents examined for flukes. The following organs were then ligatured and removed: The reticulum, psalterium, abomasum, sections of the small intestine (upper and lower), caecum, and a section of the large intestine. Faecal samples were collected from the rectum.

The liver was next examined for cysts, usually appearing as whitish spots on the surface. The bile ducts were cut into and examined for fluke infestation. The liver was cut up and the pieces squeezed vigorously to remove any flukes present. Cysts adhering to the mesentery or body wall were removed.

The lungs were examined for cysts and the trachea and bronchi slit open and examined for lungworm.

Laboratory technique

Ectoparasites. In the laboratory the hide was examined for ectoparasites using one of the following methods: (a) The brushing and hand picking technique. This was found to be the simplest and one of the most effective methods, especially in the case of the biting lice (*Damalinia longicornis*) which were hard to dislodge by other methods such as the flotation technique, although it must be emphasised here that this method was only useful for macro-parasites. The hair on the hide was parted to expose the parasites, which were usually found at the base of the hair, and the parasites were brushed out or dislodged with a dissecting needle. It was sometimes found, in the case of thick infestations, that a large number of lice could be collected by clipping the hair close to the skin surface and later sorting the lice from the hair clippings.

(b) The flotation technique. This method, described by Gering and Thomas (1953) has been used with a good deal of success by overseas workers and was found to be especially useful in the case of mites and Anoplura. Few Anoplurans and no mites were found from the red deer, so this method did not really have a fair trial, and the yield for Mallophaga by this method is recognised as being consistently low, as the mandibles of these lice firmly clasp the hair of the host and thus make removal difficult.

A piece of hide, small enough to fit comfortably into a large preserving jar, was placed in a quart jar half filled with water, to which a small teaspoonful of detergent had been added. The jar was sealed and shaken vigorously at approximately ten minute intervals over a period of two hours. The piece of hide was then removed, any adhering parasites being washed back into the jar. The solution was left for several hours allowing the parasites to settle to the bottom of the jar. The excess liquid was poured off and the residue examined. The author found, however, that the available detergents were unsatisfactory, producing an excessive amount of foam.

(c) Boiling in caustic. This was especially successful if lice were difficult to remove or were in small numbers. The hide was placed in a beaker with a strong sodium hydroxide solution. The hair dissolved away from the hide leaving the lice and skin remaining. The skin was removed and the liquid filtered off.

Ectoparasites, when isolated by one of the above methods, were placed in 70% alcohol. They were then cleared and mounted in polyvinyl-lactophenol mountant.

The mountants used were formulae MA.2, PL3 and A.3, described by Salmon (1951, 1954). Engorged ticks (*Haemaphysalis bispinosa*) were slit open with a dissecting needle and the bulk of the congealed blood removed, to facilitate mounting.

Endoparasites. The procedure for the removal of gut parasites was as follows. The organ to be examined was cut open and the contents placed in a large sieve made of sixty-gauge bronze gauze. This was found to be sufficient to retain even the smallest worms. The material in the sieve was washed thoroughly, until the water passing through ran clear. The resulting debris, which was made up of partially digested herbage and nematodes, was washed into jars and 20% formalin added. Intestine contents were forced out using a tap with a pipette attachment.

The nematodes were sorted out from the debris by one of three methods:

(a) The sieved material was diluted in a petri dish and examined on the light box and the worms removed with a dissecting needle.

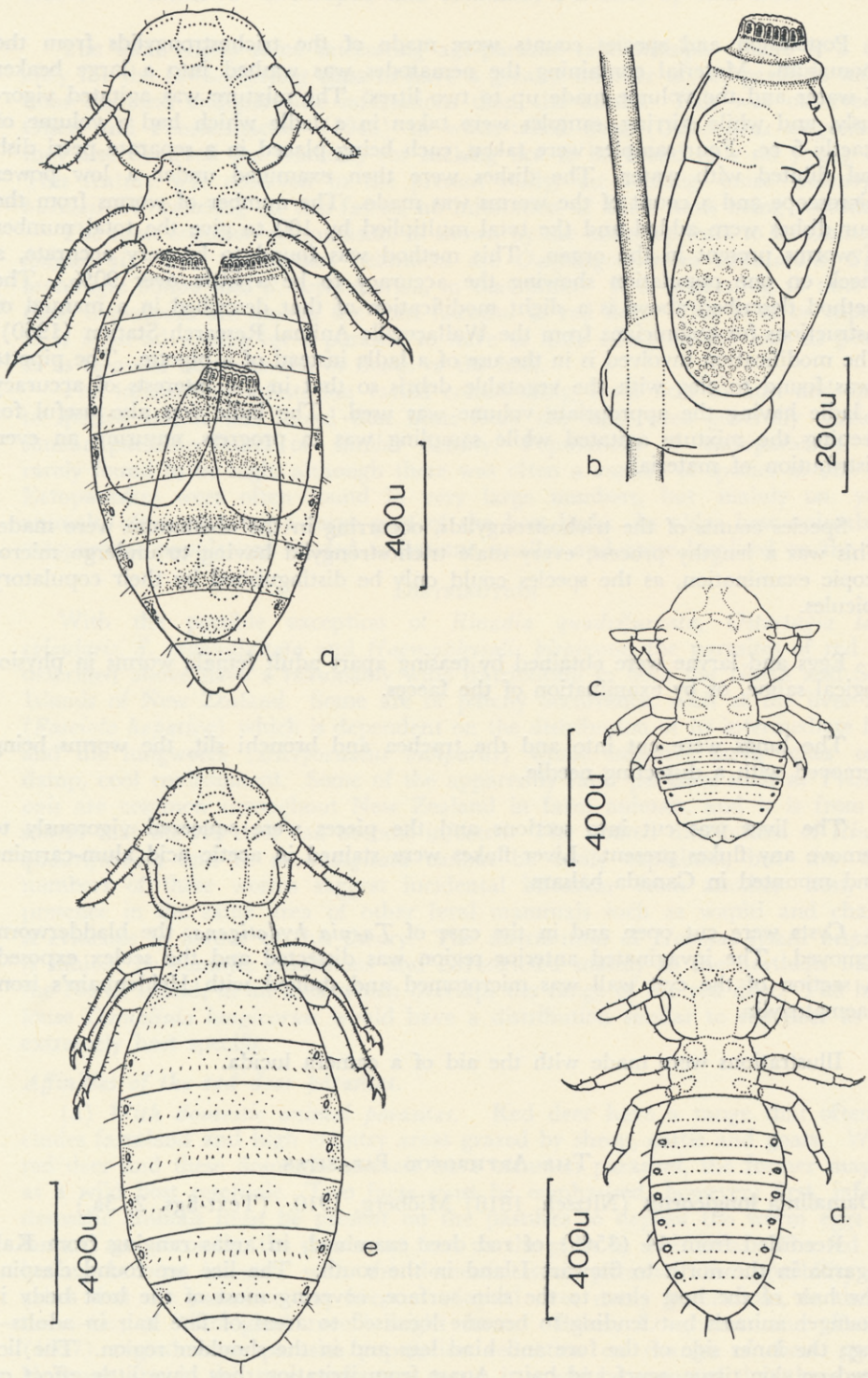
(b) For smaller nematodes an aqueous solution of iodine was added to the diluted material in the petri dish. The material was allowed to take the stain for fifteen minutes, then sodium thiosulphate was added. This rapidly decolourised the vegetable matter in the dish, but the nematodes took longer to de-stain, thus remaining conspicuous for a short period of time. This method was not found to be completely satisfactory, as to make a complete recovery, examination under a low power microscope had still to be made.

(c) For the smallest nematodes, the best method was to dilute the material in a petri dish and examine under a low-powered binocular microscope, removing the nematodes with a dissecting needle. This method was tedious but very thorough and ensured accuracy when making species counts.

Nematodes removed were preserved in 50% iso-propyl alcohol, this concentration being low enough to prevent distortion in the small nematodes.

The larger nematodes were cleared in glycerine and mounted in glycerine jelly. The most satisfactory method of clearing the specimens was found to be as follows: the nematodes were taken from 50% alcohol to 70% alcohol thence to a solution of 20% glycerine in 70% alcohol. This solution was then concentrated in a paraffin oven at 46 deg. C. The concentrated glycerine was then replaced with fresh glycerine and this was left in the oven until the nematodes had cleared sufficiently. They were then mounted in glycerine jelly. This method ensured the absence of plasmolysis.

Smaller nematodes such as the trichostrongylids needed little clearing as they were almost transparent. They were examined in physiological saline or in the fluid in which they were preserved. When trichostrongylids were mounted on a slide, the coverslip was broken to prevent too great a pressure being exerted on the specimen. To spread out the copulatory bursa of these small worms, a little light pressure on the coverslip with a dissecting needle was all that was usually required. For spicule preparations of the trichostrongylids, a polyvinyl alcohol-lactophenol mountant (MA. 2) was used. The clearing action of this medium was too harsh for normal use as a mountant, also lactophenol has the property of swelling soft tissues, thus rendering the preparations unsuitable for measurements. However chitinous structures such as the spicules and gubernaculum remained unchanged in this medium. An attempt was made to mount trichostrongylids in a polyvinyl alcohol mountant (Pl. 3) described by Salmon (1954). This mountant did not contain lactophenol, lactic acid and glycerine replacing this substance. However, specimens mounted in this medium distorted.



TEXT-FIG. 2.—The life history of *Damalinia longicornis*. a—Adult female bearing embryonated eggs. b—Embryonated egg attached to hair. c—First stage nymph. d—Second stage nymph. e—Third stage nymph.

Population and species counts were made of the trichostrongylids from the abomasum. Material containing the nematodes was washed into a large beaker of water and the volume made up to two litres. The mixture was agitated vigorously, and while stirring, samples were taken in a ladle which had a volume of exactly 5 cc. Four samples were taken, each being placed in a separate petri dish and diluted with water. The dishes were then examined under a low power microscope and a count of the worms was made. The number of worms from the four dishes were added and the total multiplied by 100 to give the total number of worms present in the organ. This method was found to be very accurate, a check on one population showing the accuracy to be a little over 90%. The method described above is a slight modification of that described in a manual of instructions for technicians from the Wallaceville Animal Research Station (1960). The modification involved is in the use of a ladle instead of a pipette. The pipette was found to clog with the vegetable debris so that in the interests of accuracy a ladle having the appropriate volume was used. The ladle was also useful for keeping the mixture agitated while sampling was in progress, ensuring an even distribution of material.

Species counts of the trichostrongylids, occurring in the abomasum were made. This was a lengthy process, every male trichostrongylid having to undergo microscopic examination, as the species could only be distinguished by their copulatory spicules.

Eggs and larvae were obtained by teasing apart adult female worms in physiological saline, or by examination of the faeces.

The lungs were cut into and the trachea and bronchi slit, the worms being removed with a dissecting needle.

The liver was cut into sections and the pieces were squeezed vigorously to remove any flukes present. Liver flukes were stained in acetic acid alum-carmine and mounted in Canada balsam.

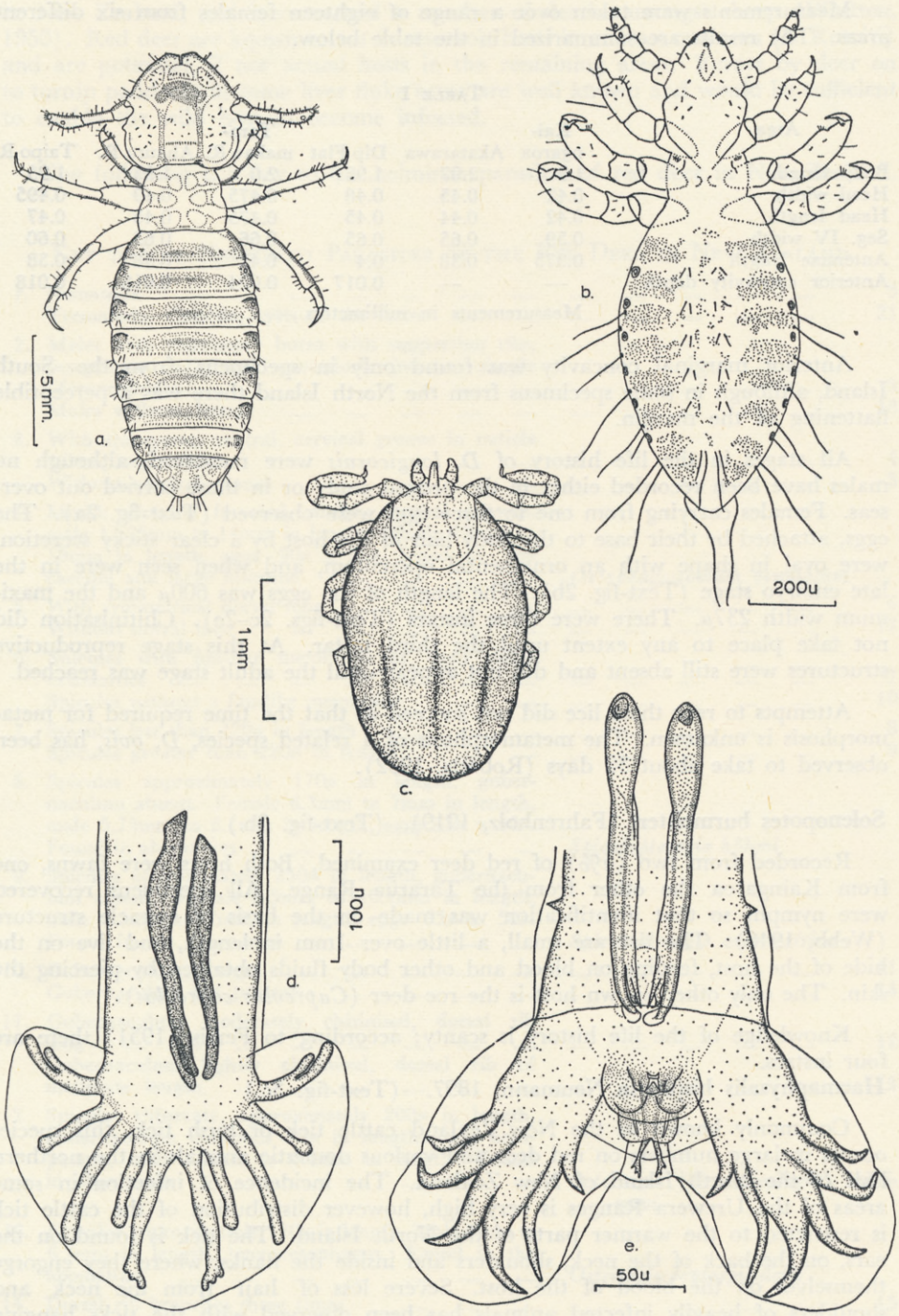
Cysts were cut open and in the case of *Taenia hydatigena*, the bladderworm removed. The invaginated anterior region was dissected and the scolex exposed. A section of the cyst wall was microtomed and stained with Heidenhain's iron-haematoxylin.

Illustrations were made with the aid of a camera lucida.

The Arthropod Parasites

Damalinia longicornis (Nitzsch, 1818) Mjöberg, 1910. (Text-figs. 2, 3a.)

Recorded from 14 (35%) of red deer examined, in areas ranging from Kaingaroa in the north to Stewart Island in the south. The lice are found clasping the hair of the host close to the skin surface, covering most of the host body in younger animals but tending to become localised to areas of fine hair in adults—e.g., the inner side of the fore and hind legs and in the shoulder region. The lice feed on skin tissue, scurf and hair. Apart from irritation they have little effect on their hosts. The only other known species of host for this louse is the wapiti (*Cervus canadensis*).



TEXT-FIG. 3.—Parasites of red deer. a—*Damalinia longicornis*, female; b— *Solenopotes burmeisteri*, nymph stage; c—*Haemaphysalis bispinosa*, female; d—*Dictyocaulus viviparus*, posterior, male; e—*Ostertagia leptospicularis*, posterior, male.

Measurements were taken over a range of eighteen females from six different areas. The results are summarized in the table below.

Table I

Area	Kaingaroa	Akatarawa	Dip Flat	Taramakau R.	Ahaura R.	Taipo R.
Body length	1.9	2.07	1.95	2.0	1.95	1.95
Head width	0.42	0.45	0.48	0.475	0.49	0.495
Head length	0.42	0.44	0.45	0.475	0.45	0.47
Seg. IV width	0.59	0.65	0.65	0.66	0.65	0.60
Antennae length	0.375	0.38	0.4	0.42	0.38	0.38
Anterior concavity depth	—	—	0.017	0.024	0.018	0.018

Measurements in millimetres.

Anterior marginal concavity was found only in specimens from the South Island, although in some specimens from the North Island there was a perceptible flattening of the margin.

All stages in the life history of *D. longicornis* were recovered, although no males have been recorded either in the present study or in those carried out overseas. Females carrying from one to three eggs were observed (Text-fig. 2a). The eggs, attached by their base to the body hair of the host by a clear sticky secretion, were oval in shape with an ornamental operculum, and when seen were in the late embryo stage (Text-fig. 2b). The length of the eggs was 600μ and the maximum width 237μ. There were three instars (Text-figs. 2c–2e). Chitinisation did not take place to any extent until the third instar. At this stage reproductive structures were still absent and did not appear until the adult stage was reached.

Attempts to rear these lice did not succeed so that the time required for metamorphosis is unknown. The metamorphosis of a related species, *D. ovis,* has been observed to take about 32 days (Roberts, 1952).

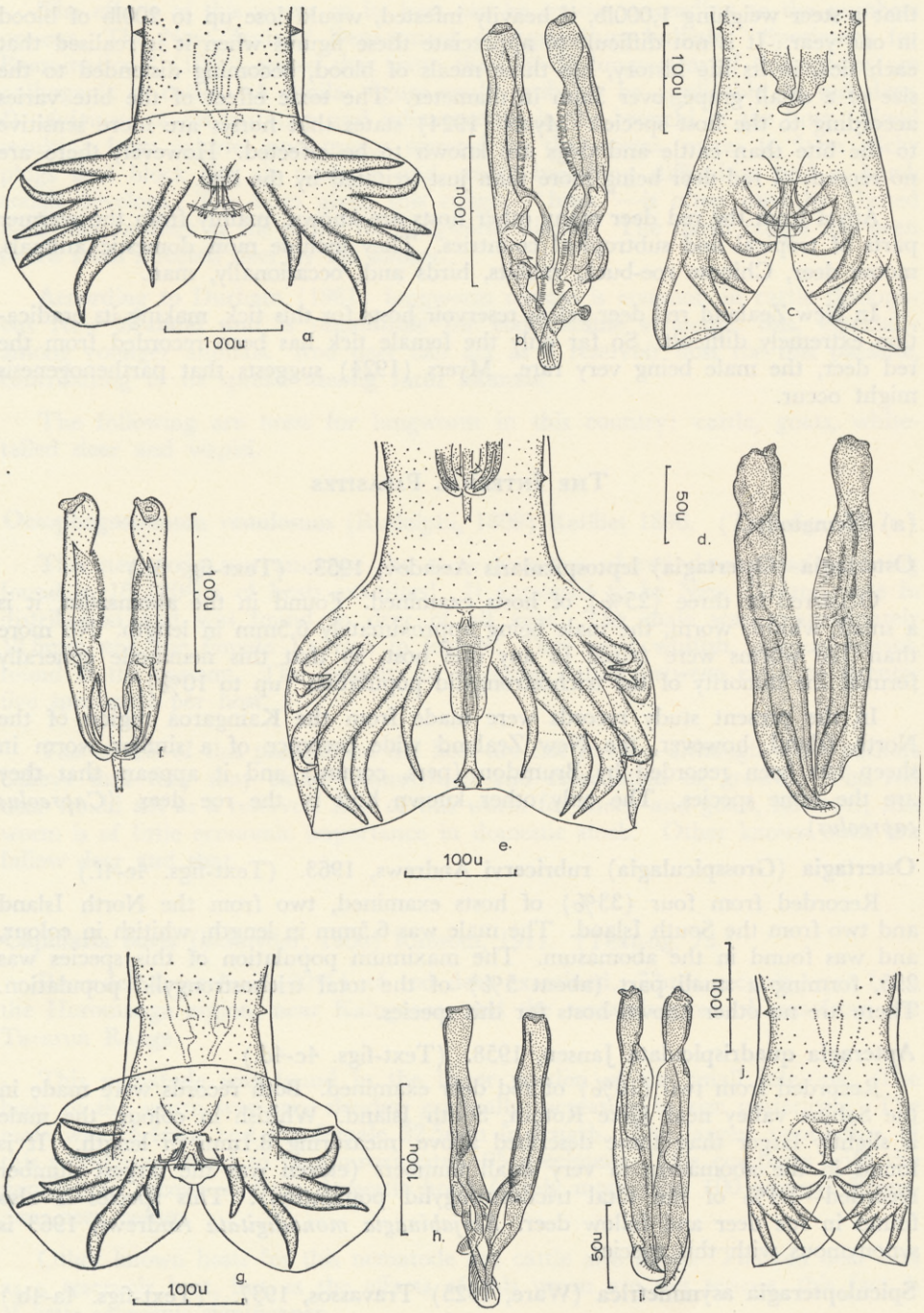
Solenopotes burmeisteri (Fahrenholz, 1919). (Text-fig. 3b.)

Recorded from two (5%) of red deer examined. Both hosts were fawns, one from Kaingaroa the other from the Tararua Range. All specimens recovered were nymphs so that identification was made on the basis of spiracle structure (Webb, 1946). The lice are small, a little over 1mm in length, and live on the hide of the host, feeding on blood and other body fluids obtained by piercing the skin. The only other known host is the roe deer (*Capreolus capreolus*).

Knowledge of the life history is scanty; according to Ferris (1951) there are four instars.

Haemaphysalis bispinosa Neumann, 1897. (Text-fig. 3c.)

Commonly known as the New Zealand cattle tick or bush tick, this species occurs in large numbers on red deer and various domestic animals in the northern half of the North Island of New Zealand. The incidence of infection in some areas of the Urewera Ranges is very high, however distribution of the cattle tick is restricted to the warmer parts of the North Island. The tick is found on the ears, on the back of the neck, shoulders and inside the flanks, where they engorge themselves on the blood of the host. Severe loss of hair from the neck and shoulders of heavily infected animals has been observed with the ticks hanging from the host like "bunches of grapes" (Newbold, 1963). Large quantities of blood may be removed from the host. Myers (1924) describes experiments undertaken by the United States Department of Agriculture, in which it was found



TEXT-FIG. 4.—a—*Spiculopteragia asymmetrica,* male, bursal region. b—*Spiculopteragia asymmetrica,* male, spicules. c—*Skrjabinagia monodigitata,* male, bursal region. d—*Skrjabinagia monodigitata,* male, spicules. e—*Ostertagia rubricervi,* male, bursal region. f—*Ostertagia rubricervi,* male, spicules. g—*Spiculopteragia böhmi,* male, bursal region. h—*Spiculopteragia böhmi,* male, spicules. i—*Rinadia quadrifurcata,* male, spicules. j—*Rinadia quadrifurcata,* male, bursal region.

that a steer weighing 1,000lb, if heavily infested, would lose up to 200lb of blood in one year. It is not difficult to appreciate these figures when it is realised that each tick, in its life history, has three meals of blood, becoming distended to the size of a small grape, over 3mm in diameter. The toxic effect of the bite varies according to the host species. Myers (1924) states that horses are more sensitive to the bite than cattle and dogs are known to be affected. However, there are no records of red deer being more than just irritated by the bite.

Apart from the red deer many other hosts are known, mainly from the warmer parts of tropical and subtropical countries. They include most domestic animals, moose deer, Chinese roe-buck, rabbits, birds and, occasionally, man.

In New Zealand red deer act as reservoir hosts for this tick, making its eradication extremely difficult. So far only the female tick has been recorded from the red deer, the male being very rare. Myers (1924) suggests that parthenogenesis might occur.

The Internal Parasites

(a) Nematodes.

Ostertagia (Ostertagia) leptospicularis Assadov, 1953. (Text-fig. 3e.)

Occurred in three (25%) of hosts examined. Found in the abomasum, it is a small, whitish worm, the male being approximately 6.5mm in length. No more than 320 worms were found in any one host, so that this nematode generally formed the minority of the trichostrongylid population (up to 10%).

In the present study records were made from the Kaingaroa region of the North Island, however, the New Zealand wide presence of a similar worm in sheep has been recorded by Brunsdon (pers. comm.) and it appears that they are the same species. The only other known host is the roe deer (*Capreolus capreolus*).

Ostertagia (Grosspiculagia) rubricervi Andrews, 1963. (Text-figs. 4e-4f.)

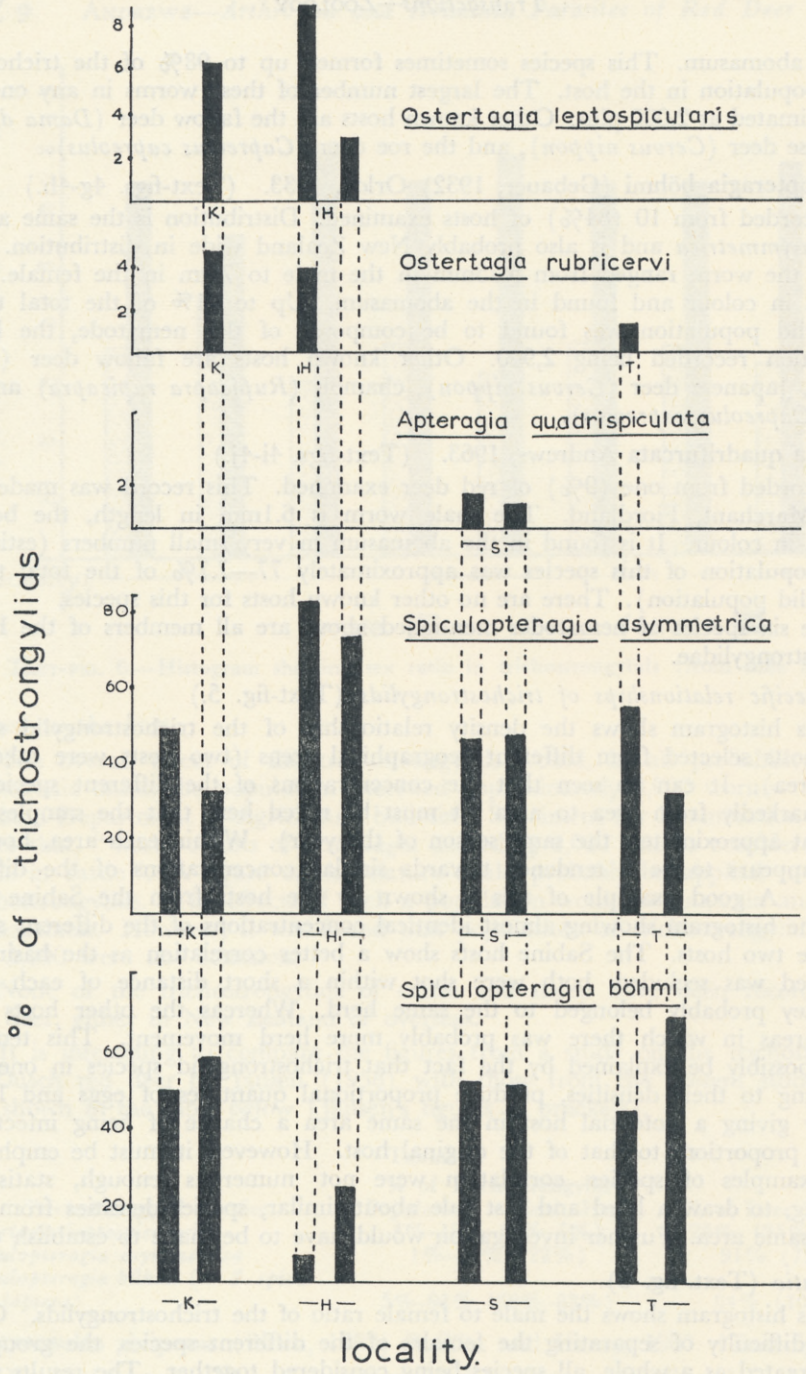
Recorded from four (33%) of hosts examined, two from the North Island and two from the South Island. The male was 6.5mm in length, whitish in colour, and was found in the abomasum. The maximum population of this species was 255, forming a small part (about 5%) of the total trichostrongylid population. There are no other known hosts for this species.

Apteragia quadrispiculata Jansen, 1958. (Text-figs. 4c-4d.)

Recorded from two (16%) of red deer examined. Both records were made in the Sabine valley near Lake Rotoiti, South Island. Whitish in colour, the male is slightly larger than those described above, measuring 8.1mm in length. It is found in the abomasum in very small numbers (eleven was the largest number recorded—1.4% of the total trichostrongylid population). This species is also found in roe deer and fallow deer. *Skrjabinagia monodigitata* Andrews, 1963 is synonymous with this species.

Spiculopteragia asymmetrica (Ware, 1925) Travassos, 1937. (Text-figs. 4a-4b.)

Occurred in 11 (91%) of red deer examined, ranging from Kaingaroa in the North Island to Lake Marchant in the South Island. It is probable that this parasite is New Zealand wide in distribution. The size of the worm ranges from 7.7mm in the male to 8.6mm in the female, somewhat larger than those recorded overseas (Jansen, 1958; Ware, 1925). It is reddish-white in colour and is found



TEXT-FIG. 5.—Histogram showing correlation in trichostrongylid species intensity in hosts from the same localities. Each vertical series of bars represents the total percentage intensity of different trichostrongylid species from one host. Horizontal reading gives correlation of species intensity between two hosts from the same area.

in the abomasum. This species sometimes formed up to 98% of the trichostrongylid population in the host. The largest number of these worms in any one host was estimated at 2,000 plus. Other known hosts are the fallow deer (*Dama dama*), Japanese deer (*Cervus nippon*), and the roe deer (*Capreolus capreolus*).

Spiculopteragia böhmi (Gebauer, 1932) Orlov, 1933. (Text-figs. 4g-4h.)

Recorded from 10 (84%) of hosts examined. Distribution is the same as that of *S. asymmetrica* and is also probably New Zealand wide in distribution. The size of the worm ranged from 5.75mm in the male to 7mm in the female. It is whitish in colour and found in the abomasum. Up to 91% of the total trichostrongylid population was found to be composed of this nematode, the largest population recorded being 2,900. Other known hosts are fallow deer (*Dama dama*), Japanese deer (*Cervus nippon*), chamois (*Rupicapra rupicapra*) and roe deer (*Capreolus capreolus*).

Rinadia quadrifurcata Andrews, 1963. (Text-figs. 4i-4j.)

Recorded from one (9%) of red deer examined. This record was made from Lake Marchant, Fiordland. The male worm is 6.1mm in length, the body is whitish in colour. It is found in the abomasum in very small numbers (estimated total population of this species was approximately 77—7.7% of the total trichostrongylid population). There are no other known hosts for this species.

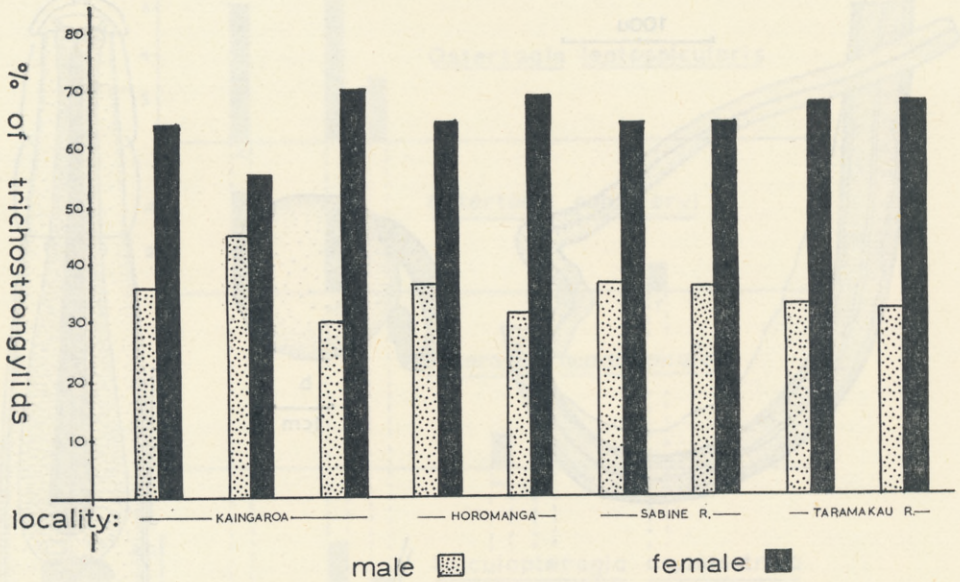
The six species of nematodes mentioned above are all members of the Family Trichostrongylidae.

Interspecific relationships of trichostrongylids (Text-fig. 5.)

This histogram shows the density relationship of the trichostrongylid species from hosts selected from different geographical areas (two hosts were taken for each area). It can be seen that the concentrations of the different species can vary markedly from area to area (it must be noted here that the samples were taken at approximately the same season of the year). Within each area, however, there appears to be a tendency towards similar concentrations of the different species. A good example of this is shown by the hosts from the Sabine River area, the histogram showing almost identical concentrations of the different species in these two hosts. The Sabine hosts show a better correlation as the basin they inhabited was secluded, both were shot within a short distance of each other, and they probably belonged to the same herd. Whereas the other hosts came from areas in which there was probably more herd movement. This tendency could possibly be explained by the fact that trichostrongylid species in one host, according to their densities, produce proportional quantities of eggs and larvae, thereby giving a potential host in the same area a chance of being infected in similar proportions to that of the original host. However, it must be emphasized that examples of species correlation were not numerous enough, statistically speaking, to draw a hard and fast rule about similar, species densities from hosts in the same area. Further investigation would have to be made to establish this.

Sex Ratio (Text.-fig. 6)

This histogram shows the male to female ratio of the trichostrongylids. Owing to the difficulty of separating the females of the different species, the group had to be treated as a whole, all species being considered together. The results would apply more to *Spiculopteragia asymmetrica* and *S. böhmi* as these two species are predominant, the other species would have little effect on the histogram, because of their small numbers. The histogram shows an almost consistent ratio in the vicinity of 65:35, females to males, regardless of the area from which the host came, the variable densities of the different species, and the time of year that the sample was obtained.



TEXT-FIG. 6.—Histogram showing sex ratio in trichostrongylids (from nine hosts).

Effect on the host

The overall effect of the trichostrongylids would, in all probability, not be pathogenic unless the population exceeded approximately 8,000 worms. The New Zealand Department of Agriculture bulletin "Specimens for Examination" (1960) states that, "worm counts of *Ostertagia* exceeding 8,000 can be considered pathogenic in cattle". A figure of this nature could probably be applied to red deer trichostrongylids. The effects of such a population would be anaemia and general unthriftiness. However, it was found that populations of trichostrongylids exceeding 5,000 were not common.

None of the trichostrongylids of cattle and sheep have been recorded from red deer, either in New Zealand or overseas.

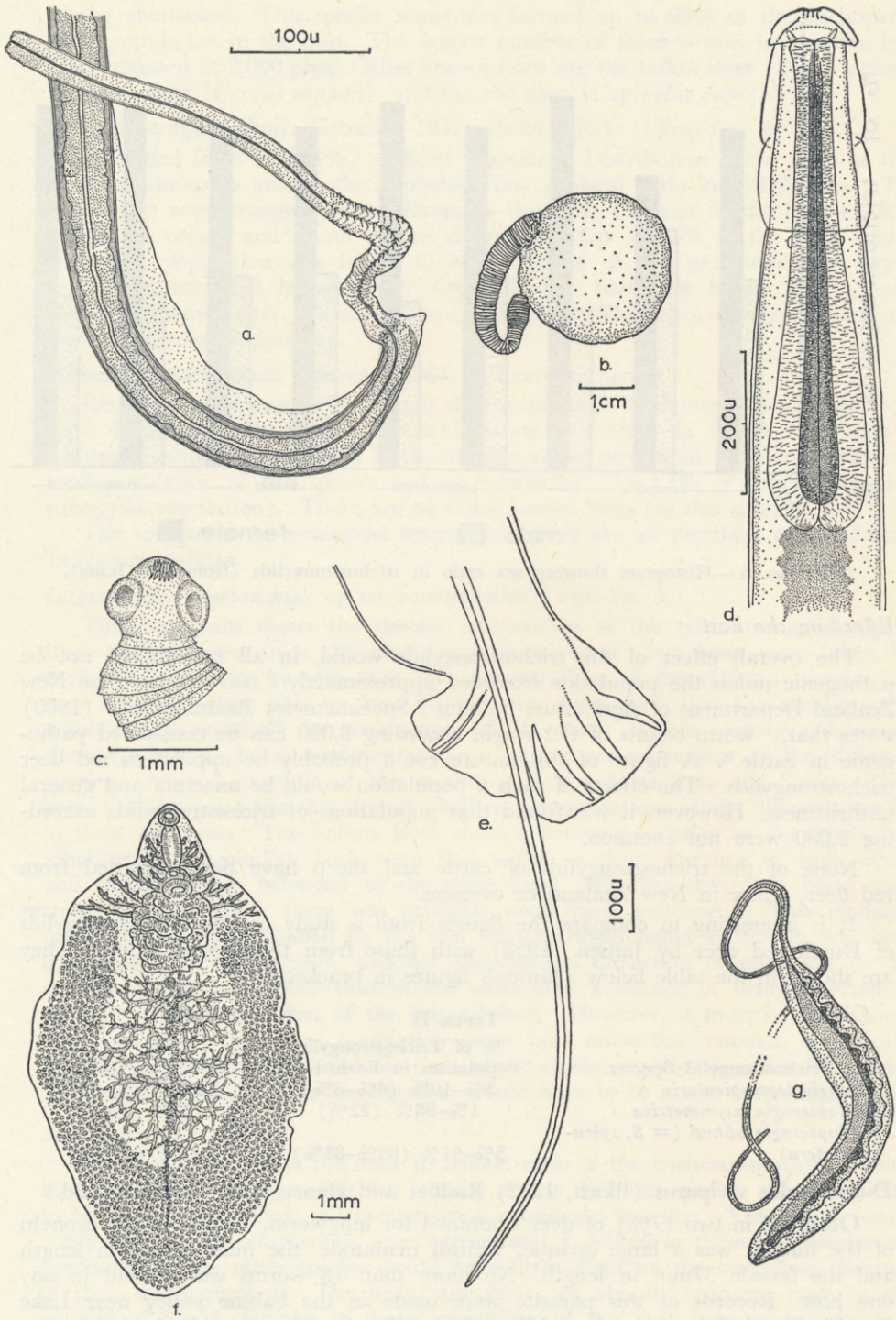
It is interesting to compare the figures from a study on the trichostrongylids of Dutch red deer by Jansen (1958) with those from the present study. They are shown in the table below (Jansen's figures in brackets).

TABLE II

Trichostrongylid Species.	% of Trichostrongylid Population in Each Host.	% of Deer Infected.
Ostertagia leptospicularis	3%–10% (4%–6%)	25% (35%–66%)
Spiculopteragia asymmetrica	1%–98% (22%)	91% (75%)
Spiculopteragia böhmi (= *S. spiculoptera*)	5%–91% (68%–83%)	84% (100%)

Dictyocaulus viviparus (Bloch, 1782) Railliet and Henry, 1907. (Text-fig. 3d.)

Occurred in two (7%) of deer examined for lungworm. Found in the bronchi of the lung it was a large opaque, whitish nematode, the male 19mm in length and the female 37mm in length. No more than 18 worms were found in any one host. Records of this parasite were made in the Sabine valley near Lake Rotoiti (South Island) and at Mitre Peak (Tararua Range). Both these areas provide an ideal environment for the development of this lungworm; wet, cool winter months and lush spring growth.



Text-fig. 7.—Parasites of red deer. a—*Capillaria bovis,* male posterior end. b—Mature bladderworm, *Taenia hydatigena.* c—Evaginated scolex of bladderworm, *Taenia hydatigena.* d—*Oesophagostomum venulosum,* anterior region, female. e—*Oesophagostomum venulosum,* posterior region, male. f—*Fasciola hepatica.* g—*Trichuris ovis,* female.

The effects of this worm on its host can be serious, according to the numbers present. The New Zealand Department of Agriculture bulletin "Specimens for Examination" (1960) stated that more than 20–30 lungworms of this species are pathogenic in cattle. A similar figure could probably be applicable to red deer. *D. viviparus* causes irritation and inflammation in the bronchi of the lung. Blood resulting from injuries and mucus secreted by the worms, mixes to form sticky plugs that block the air passages and create breathing difficulties and a harsh cough develops. The term given this cough—"husk"—is often used by United Kingdom farmers as the name for lungworm disease. The harsh cough has been heard from infected deer by the author.

According to Durham (1961) lungworm disease is common in cattle throughout New Zealand and is responsible for considerable economic loss, especially among younger animals. Red deer can act as a reservoir host for this parasite, contributing to its spread among farm animals.

The following are hosts for lungworm in this country: cattle, goats, white-tailed deer and wapiti.

Oesophagostomum venulosum (Rudolphi, 1809) Railliet 1896. (Text-figs. 7d-7e.)

This nematode was amongst the more common of red deer parasites, being found in 16 (80%) of hosts examined. It appeared to be New Zealand-wide in distribution and was found in deer of all ages. The male was approximately 12.6mm and the female 15.2mm in length. They were whitish, opaque worms, found in the caecum. The intensity of infection varied between eight to twenty-five specimens per host.

The effects of this parasite on the host are not serious, although some authors believe that they may cause malnutrition and retardation of growth. The red deer would act as a reservoir host of this worm for sheep and goats, however, this worm is of little economic importance in domestic stock. Other known hosts are fallow deer and thar.

Capillaria bovis (Schnyder, 1906) Ransom, 1911. (Text-fig. 7a.)

Recorded from four (30%) of red deer examined. Three records were from the Horomanga region, near Kaingaroa, and the remaining record was from the Tararua Range.

This nematode was found in the lower portion of the small intestine. The body of the worm was very slender, gradually increasing in size posteriorly. The male was 15.4mm and the female 22.5mm in length. The largest population of this worm was found to be approximately 95 specimens. This compares with the populations recovered from domestic hosts (rarely more than 100 worms) Brunsdon, pers. comm.

Other known hosts for this nematode are cattle and sheep. The red deer acts as a reservoir host, but as the effects of this worm are not serious, this fact is of little economic significance.

An unknown species of *Capillaria* was recorded from the red deer of Chantilly Forest by Brumpt (1911). This is possibly the same species as the above. Brumpt found that 30% of the Chantilly forest deer were infected with *Capillaria,* the same figure as was recorded for the present study.

Trichuris ovis (Abildgaard, 1795) Smith, 1908. (Text-fig. 7g.)

Recorded from one (3%) of red deer examined. This record was made from the Horomanga area (Kaingaroa). *T. ovis* was found in the caecum. It was an opaque, whitish worm with a slender anterior region and a short, thick posterior portion. The male worm was 31.5mm in length, the female 32.2mm in length. Only four specimens were taken from this host. *T. ovis* has a wide range of hosts including most domestic ruminants. Red deer would act as reservoirs, but this fact is of no economic importance as this worm has little effect on its hosts.

(b) *Cestodes.*

Taenia hydatigena Pallas, 1766 = (**Cysticercus tenuicollis** Rudolphi, 1810). (Text-figs. 7b-7c.)

The cysticerci of *Taenia hydatigena* were found in two (5%) of hosts examined, one from Kaingaroa, the other from Westland (Taipo Valley). Both cysts were found attached to the gut mesentery of the host. The cysts measured 2cm and 3cm in diameter and were whitish and translucent when fresh. One of the cysts was sterile and had started to calcify.

The cysticercus stage has been found in cattle, sheep, and goats as well as fallow deer, virginia deer and wapiti. Red deer act as reservoir hosts for this parasite, a fact of some economic significance. The embryos cause haemorrhage as they migrate through the liver, and this may kill the host if it is young. Once the bladderworms have grown to full size they generally have little effect upon the host. Infected livers from domestic stock are rendered useless as food, the lesions caused by the larvae resulting in their condemnation. Seddon (1950) records that in Australia, in 1937, the loss to one Adelaide slaughterhouse was £6,000 due to the rejection of livers as a result of this infection. Although no figures have been published, similar losses are known to occur in New Zealand slaughterhouses.

The spread of this parasite would be difficult to check. Hunters' dogs have ready access to offal (pig and deer), and infected dogs taken into the bush would leave faeces containing tapeworm eggs, thus leaving the way open for the infection of deer and other wild hosts. Sweatman and Williams (1962) record that pig dogs, rabbit dogs, and dogs from farms, forestry camps, and Maori pas are very susceptible to infection.

(c) *Trematodes*

Fasciola hepatica Linnaeus, 1759. (Text-fig. 7f.)

The liver fluke was recorded in three (7.5%) of red deer examined. All records were made at the northern end of Lake Rotoiti (South Island). The size of the flukes never exceeded 1.5cm, somewhat smaller than flukes of the same species recovered from domestic animals. The distribution of the liver fluke is restricted to those areas where the intermediate hosts (*Myxas ampulla, Limnea alfredi*) occur. These are: Hawke's Bay-Poverty Bay, Nelson (L. Rotoiti area), Central Otago and Central Westland.

The liver fluke has great economic importance as the cause of liver rot in sheep and cattle. The flukes live in the bile ducts which are thickened by the resultant irritation giving rise to the condition known as "pipey liver". The infestation of red deer hosts was not sufficiently severe to cause this condition, however the bile ducts were somewhat thicker than normal. Severe anaemia and black disease are important after-effects of fluke infestation in domestic animals

in New Zealand, and have caused a number of deaths amongst sheep (Whitten, 1950). Red deer are known to act as reservoir hosts in at least one area (L. Rotoiti) and are potential, if not actual hosts in the remaining areas. Forays by deer on to turnip paddocks in some liver fluke areas are well known and would be sufficient to enable the wild host to become infected.

The following is a key to the helminth parasites of red deer in New Zealand.

KEY TO THE HELMINTH PARASITES OF THE RED DEER IN NEW ZEALAND

1.	Nematoda	3
	Trematoda, Cestoda, cysts of the latter	21
2.	Males with copulatory bursa with supporting ribs, oesophagus club-shaped posteriorly, intestine simple (Strongyloidea)	3
	Males without bursa	18
3.	With transverse, ventral, cervical groove in cuticle (Oesophagostominae)	4
	Without cervical groove	5
4.	Mouth directed forward, shallow buccal capsule, male 11.75mm to 14mm in length, female 13mm to 19mm in length, eggs 90μ x 55μ, found in the caecum and large intestine	*Oesophagostomum venulosum*
5.	With symmetrical dorsal lobe	6
	Without dorsal lobe	17
6.	Spicules with fan-like membrane at their distal extremities	7
	Spicules without a fan-like membrane	10
7.	Spicules less than 220μ in length	8
	Spicules greater than 220μ in length	9
8.	Spicules approximately 170μ in length, gubernaculum absent. Female 6.3mm to 7mm in length, male 5.75mm to 6.1mm in length, eggs 85μ x 40μ. Found in abomasum	*Spiculopteragia böhmi*
9.	Spicules approximately 250μ in length, gubernaculum absent. Female 8.5mm to 10.1mm in length, male 6.5mm to 7mm in length, eggs 95μ x 50μ. Found in the abomasum	*Spiculopteragia asymmetrica*
10.	Gubernaculum present	11
	Gubernaculum not present	14
11.	Gubernaculum moderately chitinised, dorsal rib long	12
	Gubernaculum lightly chitinised, dorsal rib of moderate length	13
12.	Spicules trifurcate, approximately 200μ in length, gubernaculum chitinous 70μ in length, long oesophagus, male 6.3mm to 6.4mm in length. Found in abomasum	*Ostertagia* (*Grosspiculagia*) *rubricervi*
13.	Spicules approximately 170μ in length. Male 6mm to 6.3mm in length, long oesophagus. Found in the abomasum	*Ostertagia leptospicularis*
14.	Dorsal rib branches three times	15
	Dorsal rib bifid and reduced	16
15.	Spicules approximately 225μ in length. No gubernaculum. Male 8.2mm in length. Found in the abomasum	*Apteragia quadrispiculata*

16. Spicules approximately 185μ in length. Male 5.7mm to 6.5mm in length. No gubernaculum, dorsal lobe reduced, bifid dorsal ray. Found in the abomasum — *Rinadia quadrifurcata*

17. Spicules approximately 240μ in length, gubernaculum 45μ in length. Female 17.8mm to 46mm in length, male 17mm to 32.5mm in length, dorsal ray doubled, mediolateral and posterolateral ribs fused. Eggs 80μ x 45μ. Found in the bronchi .... — *Dictyocaulus viviparus*

18. Anterior portion of worm filiform, posterior much thicker 19
Worm filiform, posterior slightly thicker 20

19. Long single spicule, female 32.2mm in length, male 31.5mm in length. Eggs 70μ x 30μ. Found in the caecum .... — *Trichuris ovis*

20. Long single spicule, spicule sheath supported by membrane, female 17mm to 21.5mm in length, male 11mm to 12mm in length. Eggs 50μ x 26μ. Found in lower small intestine .... — *Capillaria bovis*

21. Flukes (Trematoda) 22
Tapeworms, as cysts (Cestoda) 23

22. Flat, leaf-shaped fluke, cone-shaped anterior, ventral sucker, cuticle armed with small spines. Approximately 13mm in length and 7.5mm in width. Eggs 140μ x 80μ. Found in the liver .... — *Fasciola hepatica*

23. Cyst bladder-like, opaque. Bladder worm scolex possessing approximately 26 hooks, four suckers. Cyst approximately 30mm in diameter. Found in gut mesentery .... — *Taenia hydatigena* (*Cysticercus tenuicollis*)

Discussion

Infestation

It was found that all red deer examined in the present study were infected with at least one of the parasites described above. In the table below the deer have been divided into three age groups. They are: (1) fawn-yearlings, (2) adults, (3) those individuals of unknown age.

Table III

PARASITE DISTRIBUTION IN DIFFERENT AGE CLASSES.

Parasite Species	Fawn Yearling	Adult	Unknown*	Total Infection
Damalinia longicornis	6	4	1	11
Solenopotes burmeisteri	2	–	–	2
Haemaphysalis bispinosa	–	–	1	1
Ostertagia rubricervi	2	2	–	4
Ostertagia leptospicularis	2	1	–	3
Spiculopteragia böhmi	2	8	–	10
S. asymmetrica	2	9	–	11
Apteragia quadrispiculata	–	2	–	2
Rinadia quadrifurcata	–	1	–	1
Dictyocaulus viviparus	1	1	–	2
Oesophagostomum venulosum	6	7	3	16
Capillaria bovis	1	3	–	4
Trichuris ovis	1	–	–	1
Fasciola hepatica	–	2	–	2
Taenia hydatigena	–	2	–	2

* Age unknown as it was not assessed by the collectors.

The table shows some interesting age-parasite relationships. There is a tendency for the fawn-yearling class to have a greater number of ectoparasitic infestations and less endoparasitic infestations than the adults. This was observed by Olsen and Fenstermacher (1943) in white-tailed deer (*Odocoileus virginianus*) they also observed the tendency for sucking lice to be found only on young deer. This feature was observed in the present study, the sucking louse *Solenopotes burmeisteri* occurring on two fawns, no infestation of adult hosts being recorded.

The most common ectoparasite, as shown by the table, appears to be *Damalinia longicornis*. The commonest helminths are *Oesphagostomum venulosum, Spiculopteragia böhmi* and *S. asymmetrica*, in that order. It is interesting to note that these nematodes are among the least harmful to red deer. This is to be expected as it is an advantage for a parasite to have as little effect on the host as possible so as to avoid host reaction or death of the host.

The intensity of infestation varied considerably, from host to host and species to species, but it was found that hosts from the same area generally carried a similar parasitic fauna of similar density. Populations of endoparasites were rarely found to be high, although there was often a variety of species in one host. Ectoparasites were often found in very large numbers, but mainly on young animals, often covering a large part of the host body. In older host animals the ectoparasite populations tended to become smaller and more localised on the host.

DISTRIBUTION

With the possible exception of *Rinadia quadrifurcata, Ostertagia leptospicularis, S. monodigitata* and *Haemaphysalis bispinosa*, the parasites of red deer described above have a reasonably wide distribution in both the North and South Islands of New Zealand. Some are of patchy occurrence, such as the liver fluke (*Fasciola hepatica*) which is dependent on the distribution of its intermediate host; and the lungworm (*Dictyocaulus viviparus*) whose infective larva relies on a damp, cool environment. Some of the apparently rarer parasites such as *Trichuris ovis* are common throughout New Zealand in farm animals, and it is from this source that the red deer can become infected. The limited distribution of *Rinadia quadrifurcata* and *S. monodigitata* cannot be easily explained, but the small numbers of these worms suggest incidental infection from another host, and presence in the same area of other feral mammals such as wapiti and chamois is evidence in favour of this theory. The distribution of *Haemaphysalis bispinosa* is limited by climatic conditions and is restricted mainly to the northern half of the North Island, in an area which overlaps the range of the red deer. The biting louse *Damalinia longicornis* would have a distribution similar to red deer as it is extremely host specific.

Affinities of the red deer parasites.

(a) *With domestic animal parasites.* Red deer have a range that often includes farmland and high country areas grazed by sheep, cattle and goats. Where red deer and these domestic animals have common parasites, the former may act as a wild host reservoir. Two facts must be emphasised, however; first, infected domestic animals must be present on the pastures to deposit the worm eggs and larvae; and secondly, the deer must feed on the grass in such areas. The red deer having become infected with the domestic stock parasites, the possibility now arises that the parasites may become adapted over many generations, to the red deer—i.e., a "biological race" might form. Baker, Longhurst and Douglas (1957) record some parasite population reduction on change of host species. However, should this race preference occur, it would be expected that there would be only a reduction in parasite numbers, not a refusal of one host to accept the parasites of another.

Table IV

RED DEER PARASITES FOUND IN DOMESTIC ANIMALS.

Species Found also in:	Cattle	Sheep	Goats
Haemaphysalis bispinosa	x	–	–
Cysticercus tenuicollis	x	x	x
Fasciola hepatica	x	x	x
Dictyocaulus viviparus	x	–	–
Trichuris ovis	x	x	x
Oesophagostomum venulosum	–	x	x
Capillaria bovis	x	x	–
**Monezia expansa*	x	x	x
**Dictyocaulus filaria*	–	x	x
**Cooperia curticei*	x	x	x
**Chabertia ovina*	x	x	x
**Haemonchus contortus*	x	x	x

* These parasites have been recorded from red deer overseas and are known in New Zealand farm animals, but have not yet been recorded from red deer in this country.

Altogether seven parasites have been found to be common to the red deer and farm animals. This is nearly 40% of the parasite species recovered from red deer. Five parasites well known in New Zealand farm animals and recorded from red deer in Europe and England, were not found in this study, possibly an examination of a larger number of animals could show some of these parasites to be present in red deer in New Zealand.

(b) *With feral animal parasites.* Little work has been done on the parasites of any other of the introduced feral mammals in New Zealand, except the wild pig (Ineson, 1954) and the cestode parasites of the fallow deer and wapiti (Sweatman and Williams, 1962). The only parasites common to red deer and wild pig in New Zealand are the bladderworm *Cysticercus tenuicollis* and the liver fluke (*Fasciola hepatica*). The following table shows those parasites common to red deer and the other feral mammals that have been liberated in New Zealand—i.e., those parasites that are capable of being shared between these animals, each acting as a potential host reservoir for the other. The ranges of those animals mentioned overlap that of red deer. For the reasons stated above the records in the table below have, for the most part, been made overseas.

Table V

RED DEER–FERAL MAMMAL PARASITE RELATIONSHIP.

Parasite Species	Wild Pig	Wapiti	Fallow Deer*	Sambar Deer	Japanese Deer	Chamois‡
Cysticercus tenuicollis	x	x	x	x	–	–
Fasciola hepatica	x	–	x	–	–	–
Dictyocaulus viviparus	–	x	–	–	–	–
Oesophagostomum venulosum	–	–	x	–	–	–
Spiculopteragia böhmi	–	–	x	–	x	x
S. asymmetrica	–	–	x	–	x	–
Trichuris ovis	–	–	x	–	–	–
Apteragia quadrispiculata	–	–	x	–	–	–

* Imperial Bureau of Agricultural Parasitology (1933).
‡ Skrjabin, Shikhobalova and Shults (1954).

Economic importance of red deer parasites.

The economic importance of red deer parasites in New Zealand lies mainly in the sharing of these parasites with farm animals—i.e., for red deer to become a wild host reservoir. There is, at present, no suggestion for lowering the ever-increasing populations of red deer through the agency of some parasite because the

most pathogenic of the red deer parasites are shared with domestic animals, and to encourage the spread of such parasites would endanger New Zealand's agricultural economy.

Economically important parasites for which red deer are reservoir hosts are the liver fluke (*Fasciola hepatica*), the lungworm (*Dictyocaulus viviparus*), the dog tapeworm (*Cysticercus tenuicollis*), and the cattle tick (*Haemaphysalis bispinosa*). The first two parasites have been known to be the cause of death among farm animals. The larval stages of *C. tenuicollis* destroy the host's liver thereby causing its condemnation for use as food for human consumption. The cattle tick has been a menace to cattle for many years. Apart from irritating the cattle, it may damage the hide, making it unsatisfactory for tanning.

The remaining parasites for which red deer act as a reservoir host (*Oesophagostomum venulosum, Trichuris ovis* and *Capillaria bovis*) are not of any economic importance as they have no apparent effect on their hosts.

Effect of parasites on the red deer.

Almost all red deer examined in this study were in good condition, the only exceptions being those animals that were infected with lungworm, which were below average condition. No case has ever been recorded, in this country, of a red deer dying as a result of parasitism. A wide variety of parasites were often found on any one host, but heavily parasitised animals were very rare. The reason for this is that the three factors that encourage serious parasitism in deer overseas are not encountered to any extent in New Zealand. They are: overcrowding, starvation and adverse climatical conditions. Overcrowding has not yet occurred as red deer have not achieved their maximum spread. Ecologically suitable areas as yet not occupied by red deer or other animals are still available. Hunting pressure would contribute to the reduction of this spread. Starvation, which is one of the results of overcrowding, has not arisen, the relatively abundant supply of palatable plants that are to be found in the New Zealand bush precluding this factor. The climate of New Zealand is milder than that of Europe, the host's country of origin, weather conditions severe enough to kill large numbers of wild animals being almost unknown in New Zealand. Thus, apart from the few pathogenic parasites mentioned above, which are of limited occurrence, the parasitic fauna of the red deer cannot be considered harmful.

Relationship to red deer parasitic fauna overseas.

The parasitic fauna of the red deer in New Zealand bears some resemblance to that found from the red deer overseas, 10 parasites described in the present account being known from red deer in other countries; however, there are numerous parasites described from red deer in England and Europe that have not been recorded in New Zealand. They are: *Dicrocoelium dendriticum, Fasciola magna, Paramphistomum cervi* (flukes), *Moniezia crucigera* (tapeworm), *Elaphostrongylus cervi, Nematodirus roscidus, Onchocera flexuosa, Skrjabinagia cervi, Protostrongylus sagittatus, Ostertagia mossi, O. lasensis, Rinadia matherossiani* and *Strongylus* sp. (nematodes). Of these the only parasites peculiar to red deer are: *Onchocera flexuosa, Elaphostrongylus cervi,* and *Skrjabinagia cervi.* These three nematodes are notable absences, especially *Skrjabinagia cervi* which was recorded in large numbers from English red deer (Cameron, 1931). Examination of further hosts may, however, reveal the presence of these nematodes. No blood parasites were recorded in the present study.

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