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ECOLOGY AND MANAGEMENT OF INTRODUCED  
UNGULATES IN NEW ZEALAND

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In New Zealand « the climate varies from subtropical  
« to subantarctic; some parts experience an annual rain-  
« fall of more than 500 cm. and others less than 30 cm.;  
« the plant formations include mangrove swamp, rain  
« forest, heaths of various kinds, subglacial fell-and  
« herb-fields, varied associations of rock and debris, sub-  
« antarctic southern-beech forest, associations in and  
« near hot springs, dunes, salt meadows, steppes, swamps  
« and moors—in fact, for an equal variety an ecologist  
« would have to explore one of the larger continents in its  
« entirety. Further, the isolation of the region for a vast  
« period of time far from any other land-surface; the  
« absence of grazing animals, the Moa (*Dinornis*) [and  
« a few other large herbivorous flightless birds] excep-  
« ted; the diverse floral elements (Malayan, Australian,  
« Subantarctic, etc.); the strong endemism; the numerous  
« small islands where conditions are simpler than on the  
« larger ones; and, finally, the presence of many areas  
« whose vegetation has been changed within a very few  
« years through the farming operations of the settler,  
« and its components replaced by exotics of quite dif-  
« ferent growth-forms—all these attributes much enhance  
« the importance of New Zealand for ecological research. »

(L. COCKAYNE, 1912).

This environment prior to the arrival of Man in New Zealand had only two species of bats as lands mammals. Two more species—a rat (*Rattus exulans*) and a dog were introduced by Maoris arriving from Polynesia in the 14th century. Since the discovery of New Zealand by Captain COOK in 1769, the settlement of this country has

been accompanied by the arrival of domestic animals and closely followed by the liberation of a large number of wild introduced birds and mammals (THOMSON, 1922). The purpose of this paper is to describe briefly the introduction of fifteen species of ungulates which have become established in the wild state, their spread and present distribution, followed by an assessment of their population trends and some comments as to their effect on the soil and vegetation. Finally a brief outline is given of management and its results.

#### LIBERATIONS, SPREAD AND PRESENT DISTRIBUTION

The following fifteen species of ungulates are now established in New Zealand : Red Deer (*Cervus elaphus*), Fallow Deer (*Dama dama*), Japanese or Sika Deer (*Cervus nippon*), Sambar Deer (*C. unicolor*), Javan Rusa Deer (*C. timoriensis*), Wapiti (*C. canadensis*), Virginia or White-tailed Deer (*Odocoileus virginianus*), Moose (*Alces americana*), Chamois (*Rupicapra rupicapra*), Thar (*Hemitragus jemlahicus*), feral (1) goat, pig, horse, cattle and sheep.

Chamois, thar and all species of deer were introduced for sport. The importance, complexity and variety of the ecological and economic problems involved are now being recognized and a number of papers about introduced ungulates in New Zealand have been published during the last decade. A survey of introduced mammals carried out in 1946-48 (WODZICKI, 1950) provides a yardstick for assessing the position in 1959. The present report is based on recent literature and on reports and information supplied by the New Zealand Forest Service who are now responsible for the management of most wild mammals, including ungulates, in this country. In the following text, names in brackets signify personal communications supplied to the writer during the preparation of the present report in 1959.

#### Red Deer (*Cervus elaphus* L.)

The first liberation of deer originating from English parks took place near Nelson, South Island in 1851, followed by another in the Wairarapa, North Island in 1862, and later by others at Rakaia Gorge, Palmerston and Lake Hawea in the South Island. These early liberations led to the establishment of several deer herds, which for many

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(1) Feral animals are those which have reverted from the domestic to the wild state.

years remained separated from one another by large tracts of deer-free country. However, towards the end of last century, acclimatisation societies interested in fees from licences or perhaps in the extension of their sport,

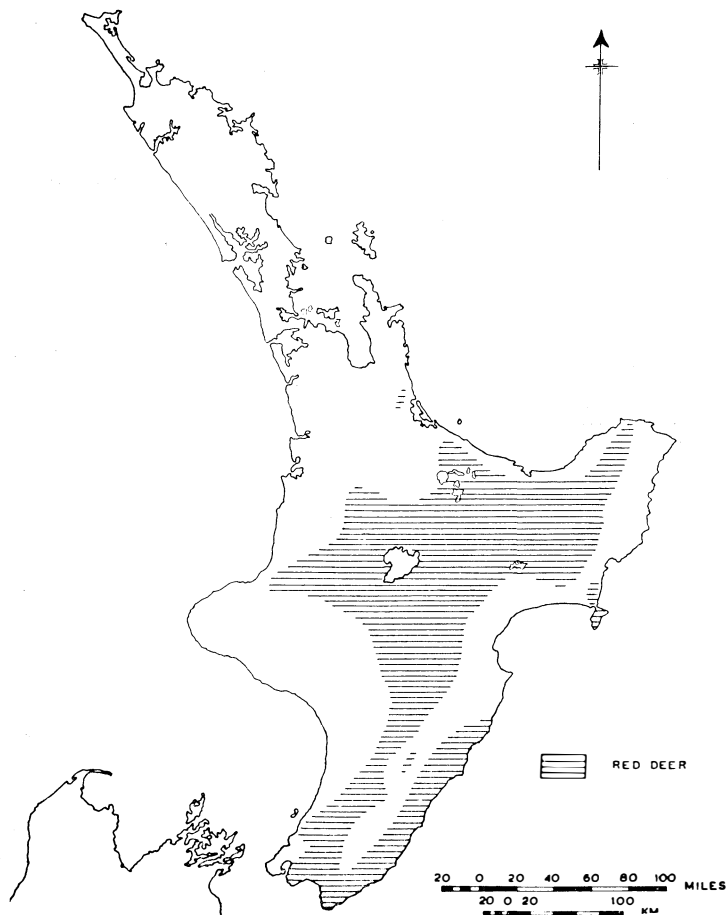


Fig. 1. — Distribution of red deer in the North Island.

became actively concerned with further liberations of deer, particularly from New Zealand stock, and fawns reared at game farms were annually liberated in various places. From the early years of this century until the First World War the Government Tourist Department took an active interest in deer and co-operated with the acclimatisation societies in liberating red and other deer species in various localities in the two main islands and on Stewart

Island. Altogether over a hundred liberations were made between 1851 and 1923 (RINEY, 1956b).

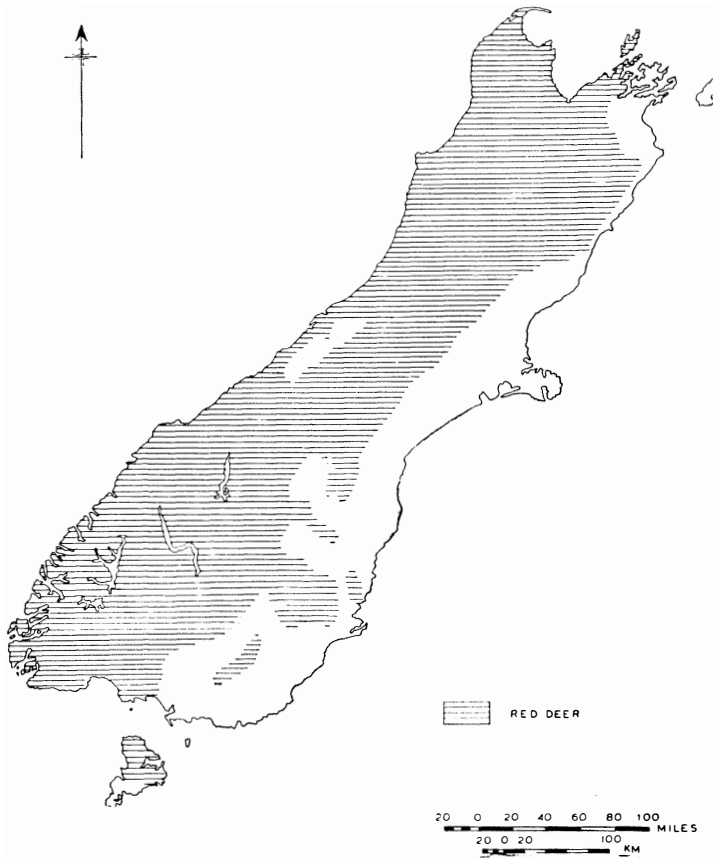


Fig. 2. — Distribution of red deer in the South Island.

As a result of these activities and of natural spread, by 1924, deer were established discontinuously in most of the mountainous areas from the Bay of Plenty in the North Island to Southland in the South Island. After liberations ceased in 1924 (C.L. BATCHELER), considerable further dispersal took place, and by 1947 deer-free areas between the various herds had largely disappeared (WODZICKI, 1950, p. 184-5). Figs. 1 and 2 show the approximate distribution of red deer in 1959. In comparison with 1947 the range of deer has markedly increased : in the North Island they have spread to the northeast of Gisborne and in the western parts of Taranaki; in the

South Island a large gap between northern and southern Westland is in the process of being filled and red deer are still spreading into the remoter parts of Fiordland; and they are present throughout Stewart Island. With only the northern part of the North Island and the south-eastern part of the South Island almost free of deer, it is likely that dispersal and establishment of red deer in new areas is nearing an end.

Red deer is widespread because it is so well adapted to any country where forest, scrub and grassland or open mountain tops lie close together. The highest populations in New Zealand are found in such areas but smaller numbers exist also in scrub areas or in forest. Beech forest is more favoured than hardwood forest (WODZICKI, 1950, p. 187); in the latter the parts most used are ridges, easy basins, sunny slopes and landslips (J. T. HOLLOWAY). As a further illustration of red deer adaptability to the New Zealand environment is their presence in the open pastoral country of Marlborough and in the exotic forest of Kaingaroa where they act much as they do in Europe causing damage to coniferous trees. Deer are more numerous and more widely spread in the South Island than in the North Island—particularly in the Southern Lakes district where some of the heaviest densities exist (RINEY 1956 a and b). Climatic, orographic and vegetational factors probably combine in favouring deer in the South Island.

Red deer, the most successful deer established in New Zealand, seem to fill a niche hitherto unoccupied. No other introduced mammal, except perhaps the rabbit, is economically as important as the red deer.

#### Fallow Deer (*Dama dama* L.)

One consignment of fallow deer imported from the Spanish Pyrenees was liberated in the vicinity of Taurangi, North Island, but other liberations were of imported English park stock (RINEY 1955); 25 liberations were made, and today fallow deer are found in 14 separate areas, mostly around or on lands adjacent to original liberation localities (Figs. 3 and 4).

The distribution pattern of Fallow deer in New Zealand raises some interesting points. Firstly we note the great tenacity of fallow deer in remaining near the liberation points. Most of these small herds have survived remarkably well despite farmland subdivisions and a growing human population with consequent increasing hunting pressure. In some other areas, such as near Wanganui in the North Island, and in the Caples and Greenstone valleys and in the Blue Mountains in the South

Island, herds of fallow deer have remained stationary for a period, both in area occupied and in numbers, and then since 1947 (WODZICKI, 1950, p. 208), have shown an almost explosive increase in numbers; some of these herds, by extending their range, have become an economic problem, and the New Zealand Forest Service reports that during a recent campaign 6,000 fallows deer were shot on approximately 20,000 acres of the Blue Mountains forest.

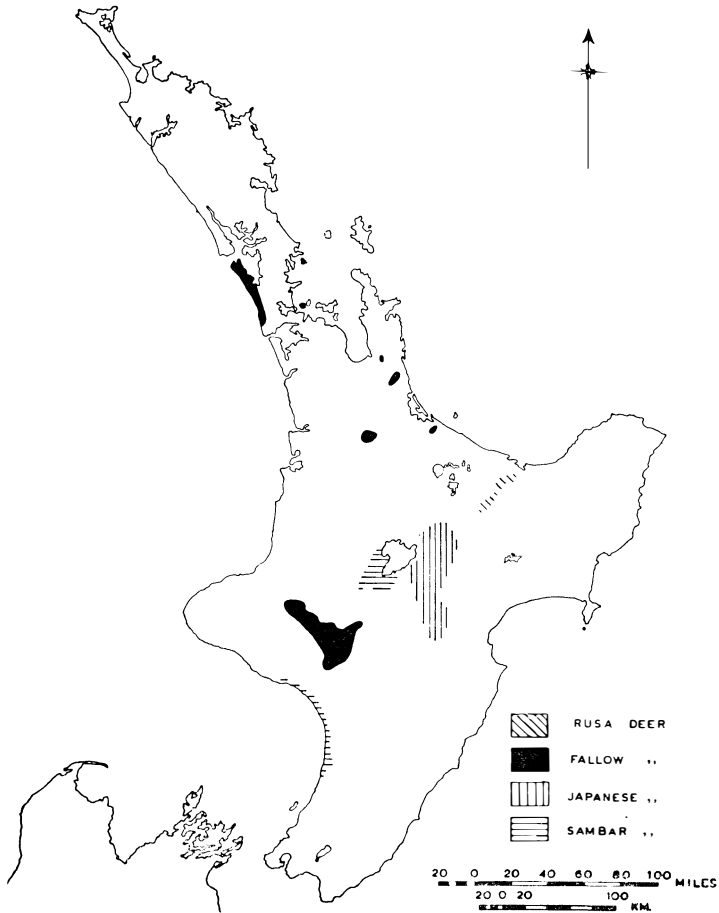


Fig. 3. — Distribution of fallow, Japanese, sambar and Javan rusa deer in the North Island.

Fallow deer in New Zealand live in scrub and bush areas of low altitude, mostly with a moderate rainfall, and often adjacent to farming lands. There is some evidence that fallow deer have habitat requirements somewhat different from red deer (fig. 3) and that they are

more specialised feeders. It has been suggested that the recent spread and increase in numbers of some of the New Zealand herds (S. FORKERT) occurred only after the vegetation was considerably modified by fallow deer themselves (e. g. Blue Mountains herd) or by red deer in adjacent country (Caples and Greenstone herd).

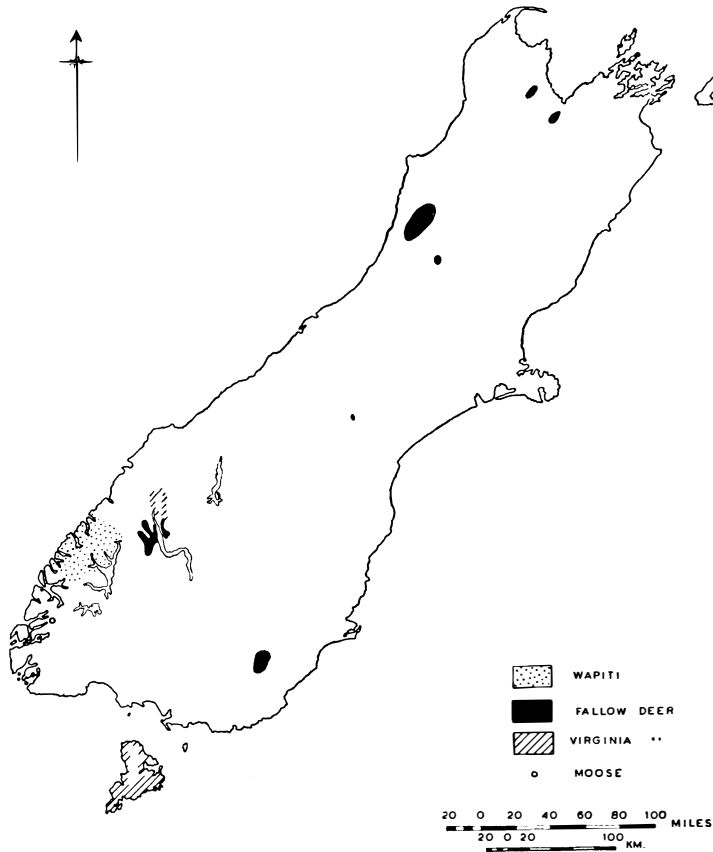


Fig. 4. — Distribution of fallow and Virginia deer, wapiti and moose in the South Island.

Japanese or Sika Deer (*Cervus nippon*).

This Asiatic species was introduced from Manchuria. Seven deer were liberated in the Northern Kaimanawa ranges, North Island in 1905. By 1947 these elusive bush-dwelling deer had extended their range considerably within the forest areas of the Kaimanawa range (WODZICKI, 1950, p. 211-3). Recent reports state that Japa-



nese deer are still spreading in three directions, and that they now occupy a territory of some 4,000 square miles (P. C. LOGAN). The present distribution of Japanese deer is shown on Fig. 3.

Two reasons may be advanced to explain this recent spread of Japanese deer. MCKELVEY (1959) has found evidence « that red deer reached a population peak without human interference in the Kaimanawa Range some 25 years ago and now are present in much lower numbers. » From the fact that red deer shot recently within the Japanese deer range were unthrifty while Japanese deer were « obviously in good condition » MCKELVEY infers that the carrying capacity of these forests « lowered by red deer to their own detriment, is still sufficiently high to support a considerable Japanese deer herd. » It is therefore possible that Japanese deer succeeds other browsing animals such as red deer, feral goats, sheep and cattle, all these species having occupied at one time a part of the present Japanese range.

Another view, put forward by sportsmen, claims that extensive shooting of the dense Japanese deer population round their initial liberation area was a major factor leading towards dispersal and the occupation of the present range.

#### Sambar Deer (*Cervus unicolor*).

Sambar, originally liberated in the Rangitikei district, North Island, in 1875 came from Ceylon. Most of the country occupied by Sambar (Fig. 3) is swampy with dense stands of manuka (*Leptospermum*), bracken, fern, lupin, New Zealand flax (*Phormium*), and giant bunchgrass (toe-toe), adjacent to coarse grass pastures (RINEY, 1957). Forest, both native and exotic, is apparently only used for shelter. In 1947 the Sambar population in the Manawatu was estimated at 400-500 animals (WODZICKI, 1950, p. 217) but in view of the heavy hunting pressure it may now be less.

The subsequent successful liberations in the central plateau, North Island, were made with animals from the Manawatu herd. A population now exists in the southern side of Lake Taupo, and there are smaller herds south east of Rotorua and in the watershed of the Whakatane River draining into the bay of Plenty.

Sambar in New Zealand have dispersed little—perhaps because of heavy shooting and their habitat requirements.

Javan Rusa Deer (*Cervus timoriensis*).

It was RINEY (1955) who first recognised the introduction of Javan rusa deer as a separate liberation from that of Sambar (*C. unicolor*). Rusa deer from New Caledonia were set free in an area near Galatea, in Kain-garoo district, North Island, in 1907 (RINEY, 1955). In contrast to other deer species which spread radially, the small rusa deer population now occupies a narrow belt of country not far from the liberation point (Fig. 3). They live in swamp and scrub country and do not normally penetrate very far into the bordering native forest. It is reported (J. B. HENDERSON) that rusa deer, being established in comparatively easy and accessible country, are much hunted for their heads, and their numbers, apparently never large, are at present dwindling.

Wapiti (*Cervus canadensis*).

Fifteen wapiti acquired in the United States were liberated in 1905 at the head of George Sound, Fiordland (DONNE, 1924, p. 170). The interest New Zealand sportsmen had in this, the only Wapiti herd in the Southern Hemisphere, resulted in more observations being recorded on Wapiti than on other species of deer in New Zealand.

The spread of wapiti has been slow. It was probably influenced by two factors—the precipitous nature of the country and, at a later stage, by the spread of red deer from adjacent parts of Fiordland. Fig. 4 showing the present range of wapiti was based on information from the New Zealand-American Fiordland Expedition (POOLE, 1951) and from K. H. MIERS who carried out a special survey of wapiti in 1955. A comparison of the present distribution with that of 1946 (WODZICKI, 1950, p. 205) shows a substantial extension. High mountain ranges, lakes and the presence of adjacent red deer populations seem to militate against further dispersal of wapiti.

In 1949 MURIE (1951) estimated the total number at under 500. K. H. MIERS, however, who knows most of the wapiti country, estimates the present population at approximately 2,000 animals.

Virginia or White-tailed Deer (*Odocoileus virginianus*).

Both liberations made by the Government in 1905 of this small American deer were successful : nine animals were liberated at Port Pegasus, Stewart Island, and another nine on the western side of Lake Wakatipu. They

became established in both areas (Fig. 4), although they increased at different rates : the Wakatipu herd remained confined to a very limited area and only recently began to extend its range towards Forbes Mountains (J. T. HOLLOWAY). On the other hand the Stewart Island herd increased rapidly and in 1947 they were « reported from most of the coastal bush-covered parts of the island » (WODZICKI, 1950, p. 218). According to recent information (C. M. SCHOFIELD) Virginia deer are now found all over the island with the exception of the mountains tops and subalpine scrub.

Moose (*Alces alces*).

The liberation of 10 Canadian moose at the head of Dusky Sound in 1910 resulted in the establishment of a small population of this species (DONNE, 1924, p. 150). This area of terrain with steep slopes is covered with dense forest and has a rainfall estimated at well over 2,600 millimetres per year (GARNIER, 1958). Less is known of the population trends and present status of Moose than of any other introduced ungulate, and this is due to the remoteness and inaccessibility of the area in which they live.

From information supplied by K. H. MIERS the area at present occupied by moose (Fig. 4) is smaller than that recorded in 1947 (WODZICKI, 1950, p. 213). In contrast to other species of deer established in New Zealand, moose seem to be slowly dying out. Various reasons for this decline may be advanced : the steepness of the valleys preventing the use of the mountain tops, the unfavourable climate, and the infiltration of red deer. There is some evidence (WODZICKI, 1950, p. 24) that since the establishment of the Moose in the second decade of this century red deer have gradually occupied all the surrounding country and perhaps now have even penetrated within the remaining range of the Moose in Dusky Sound.

Chamois (*Rupicapra rupicapra*) and Thar (*Hemitragus jemlahicus*).

These two species seem to occupy similar niches, live on the same range and also present similar problems of management. For these reasons they will be described together.

The Chamois in New Zealand originated from the Austrian Alps. There were two liberations, 7 animals in 1907, and 3 in 1913, both in the Mount Cook area, South Island. Chamois must have increased rapidly because within 10 years up to twenty animals could be counted

in one herd (WODZICKI, 1950, p. 170). Since then they have dispersed widely both northwards and southwards and by 1947 have occupied both sides of the main range some 200 kilometres to the north and about 120 kilometres to the south from the site of liberation. Fig. 5 compares the distribution of chamois in 1959 with that

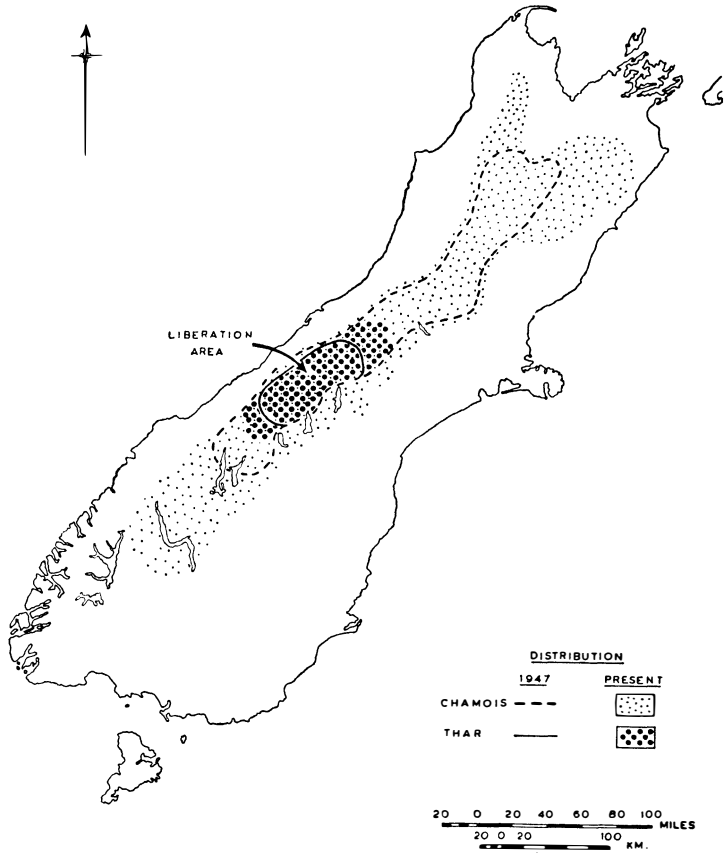


Fig. 5. — Distribution of chamois and thar in the South Island.

recorded in 1947 (WODZICKI, 1950, p. 171). Their present area extends 360 kilometres north and about 230 kilometres south from the original liberation point. It appears that chamois have dispersed more widely and at a much faster rate than any other ungulate introduced to New Zealand. The steep rocky regions of the South Island Alps are their habitat. In summer they visit the open tussock grasslands up to the snowfields but in the

autumn they return to scrub and subalpine forest. According to J. T. HOLLOWAY who has had considerable experience with this species in many localities, chamois in Canterbury come down, particularly in winter, to lower altitudes than in Europe : individual animals are often found as low as about 470 metres. It appears that chamois have at present occupied all the area suitable for them in the South Island—some of the mountain tops in Fiordland being the only likely exceptions.

Thar were introduced from Northern India in 1904 and 1909, a total of 13 animals being liberated in the vicinity of Mount Cook; here they occupied areas of high altitude forest, montane scrub and tussock country, a habitat not unlike that of the Chamois. Like chamois thar have thrived and soon increased in numbers but did not extend their range as far as did chamois : about twenty years after their first liberations herds of about one hundred animals were reported (WODZICKI, 1950, p. 172). In 1947, thar occupied an area approximately 38 kilometres wide extending some 48 kilometres to the north and about 56 kilometres to the south of Mount Cook. Since then thar have substantially extended their area and are at present found about 80 kilometres north and approximately 80 kilometres south from the liberation point (Fig. 5).

It appears that both chamois and thar have taken advantage of ecological niches not occupied by any similar form and have firmly established themselves along the main divide of the South Island. Of these two species thar have more gregarious habits and they are often found in herds of up to 60-80 animals, while chamois are usually found in much smaller groups. Thar occupy a narrower altitudinal range and are reported to graze more closely than chamois (R. FRAZER).

#### *Feral Goat.*

Captain COOK liberated the first goats in New Zealand, and, partly as an emergency food supply, other liberations were made by early sealers and whalers on several outlying islands. From the end of last century another important source has been from goats which were kept either for domestic purposes or for checking weeds and which escaped into the forest where they became feral with the ease peculiar to goats everywhere. The large and well established goat populations in parts of Hawke's Bay, on Mount Egmont and in Marlborough owe their origin to goats kept to control weeds. Goats are still

used for control of blackberry (*Rubus* spp.) and it is very likely that in the future more will escape.

The distribution of feral goats in 1959 (Fig. 6 and 7) shows only small differences from that in 1947, attributable to a slightly different approach in this paper.

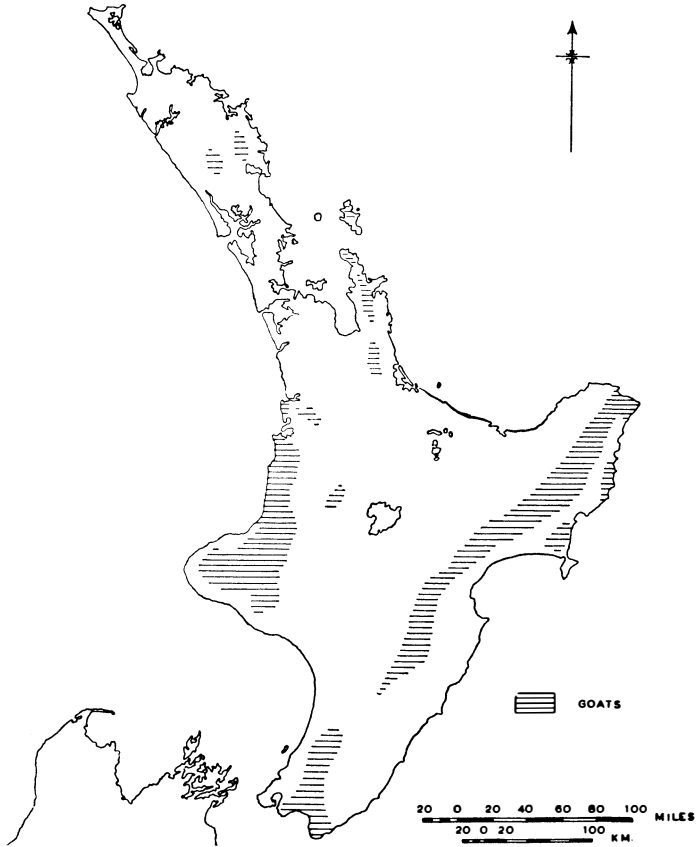


Fig. 6. — Distribution of feral goats in North Island.

Feral goats are widely distributed in varied environments both in the comparatively dry eastern districts and also in much wetter areas such as on Mount Egmont, North Island, and in southern Westland, South Island, where rainfall exceeds 2,500 mm. per annum (GARNIER, 1958). Goats often live near the forest edge adjacent to farmland or even within the forest where it has been opened up by deer or other animals. The range of a herd is small and fairly well defined and there are other fea-

tures of their social behaviour that allow goats to utilize a greatly depleted environment or to adjust themselves to high rainfall country (RINEY and CAUGHLEY, 1959).

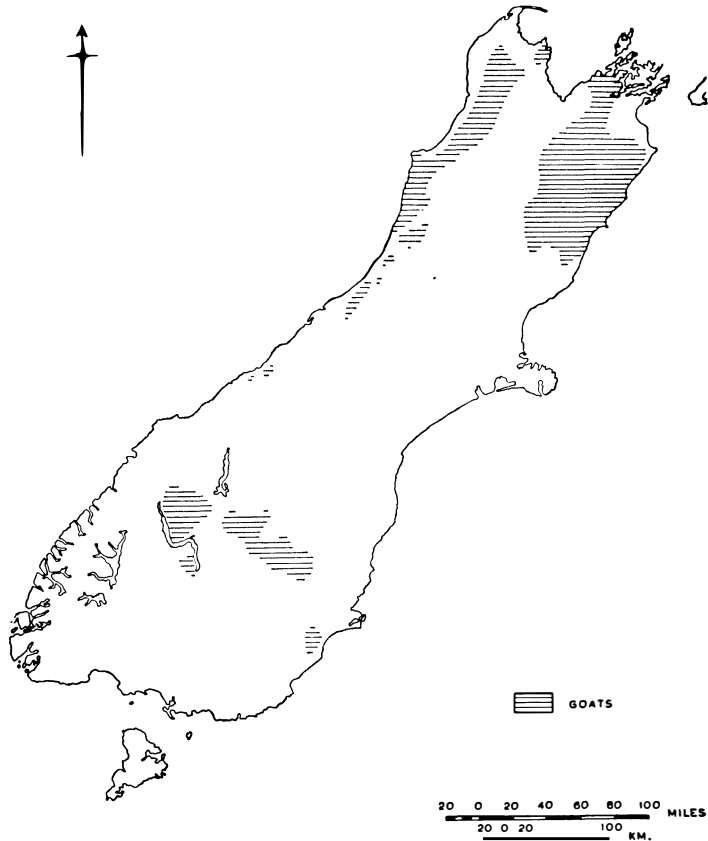


Fig. 7. — Distribution of feral goats in South Island.

#### Feral Pig (*Sus scrofa*).

The first pigs were liberated by Captain COOK, and later others were introduced by sealers and other early mariners and settlers. The liberations were partly made to supply the Maoris with a new domestic animal, and partly to supply stranded voyagers with food on outlying islands. In addition the half-wild state of pigs kept by Maoris and by some settlers, particularly in the vicinity of native forest, led to the repeated reinforcement of the already apparently well spread feral pig populations. By 1840 pigs were established throughout both main

islands and on a number of outlying islands such as Chatham Islands in the east, Auckland Islands and on Stewart Island in the south and Poor Knights and Great Barrier Islands in the north. On the two main islands in 1946 feral pigs were found from the North Cape to Southland and in some outlying islands, practically everywhere where there was sufficient and suitable cover (WODZICKI, 1950, p. 232).

Since the 1946 survey pigs were exterminated on Stewart Island (C. M. SCHOFIELD) but otherwise their present distribution remained unchanged. Local densities of pigs fluctuate because of their nomadic habits and of the temporary effect of control measures. Although pigs may be found up to upper limits of forest they remain most of the year on lower country in native forest, pine plantations, and, in their densest populations, round marginal farmland in fern, scrub or tussock country and in second growth native forest on good soils. Pigs are reported to be more numerous in the North Island, the high altitude and very heavy rainfall probably preventing their spread to large parts of the South Island.

#### *Feral Horse, Cattle and Sheep.*

These three species are briefly discussed together because of their similar origin of liberations. From the early settlement up to the present day some stock, particularly in the marginal farming areas, escaped mustering and eventually became truly feral (WODZICKI, 1950, p. 151-3).

Small herds of feral horses, once seen in rough grass and scrub-covered areas, are now mainly to be found in openings in forest plantations on the Central Plateau of the North Island.

Feral cattle are reported from the forest in the more remote country of the North Island and in the north eastern and north western parts of the South Island. The numbers of feral cattle have been reduced in recent years, and although locally they may have a serious effect on the vegetation they do not present important problems.

Feral sheep occur in the high country of the South Island and in drier parts of North Island and are important in areas where they occur together with deer and feral goats. The abundance of feral sheep is indicated by the fact that 15,687 such animals were destroyed between 1951 and 1958 by official hunters and under a bounty scheme.



## POPULATIONS TRENDS

The evidence on liberations, subsequent spread and present distribution recorded in the previous section suggests that the 15 species of introduced ungulates established in wild state in New Zealand have different population trends and have achieved varying population densities.

With regard to population trends the position with some species is still fluid as their dispersal and adjustment in new territory is still in progress, but two main groups can be distinguished : (a) ungulates which have adapted themselves to a restricted variety of habitats and established local populations within short distances of their liberation points and (b) those with a great adaptability to various habitat types and substantial powers of dispersal over large areas where they are building dense populations.

(a) Several species of deer, such as moose, sambar, Javan rusa, Virginian deer, and also other animals such as thar and feral domestic stock with the exception of pigs belong to the first group; these species seem to use the area where they are established much more severely than the animals belonging to the second group. One species—the Moose—is at present dwindling in territory and population and seems to be approaching extinction. Japanese deer and some populations of fallow deer, after remaining many years restricted in territory or numbers, have passed into an eruptive stage and are greatly increasing in population or territory or both. Finally thar and feral goats show, in two different habitats, the same tendency for building up high local populations and have a similar ability to utilize a greatly depleted environment. Although social organization of a feral goat herd (RINEY and CAUGHLEY, 1959) does not favour wide dispersal, thar have slowly but steadily increased their range.

(b) Red deer and wapiti, chamois and feral pig have all dispersed over comparatively large distances; most of these species have occupied a wide range of habitat and some are still building up their numbers. The Wapiti, possibly because of the nature of the country it occupies in New Zealand and competition with red deer, is rather a border case and it is not likely to occupy new territory or to increase much in numbers in future. Feral pigs, perhaps owing to Maori stock and farm escapes, have spread very widely and occupied all suitable habitat; with the exception of a few marginal farming areas where this species may locally build up to high num-

bers, the feral pig seems to approach a static position in spread and population (Tables 1 & 2). Finally, red deer and chamois are the most successful colonizers, and both are still increasing in territory and population. As HOLLOWAY (1950), RINEY (1956 b) and RINEY *et al.*, (1959) have shown, red deer have a great adaptability to a variety of habitats and there is evidence of their continuing further spread and increase in numbers, particularly in certain areas. Chamois has also shown a very wide dispersal, probably because its New Zealand alpine niche is particularly favourable, possibly superior to that in Europe.

There is very little information on the actual population densities of various introduced ungulates in New Zealand. On Great Island (Three Kings group, to the north west of North Auckland) all the feral goats, numbering 393 animals, were exterminated in 1946, a population density on this island of one goat to 2 acres (TURBOTT, 1948). Goats were present there at least from 1889 and most of the island had become occupied by an unpalatable *Leptospermum ericoides* subclimax vegetation (BAYLIS, 1948); feral goat densities in less depleted areas may well be higher. Feral pigs in Stewart Island have been exterminated (C. M. SCHOFIELD) but no record of numbers killed is available.

Results of shooting by official hunters in the years 1951-55 (RINEY, 1956) provides indirect information on the density of deer populations. The estimate of density was based on field officer's « assessment of the number of deer a competent shooter could be expected to record as killed during a six months' shooting season if all areas in the district under consideration were being systematically hunted. » There were five degrees of density: heavy—over 500, medium—250-500, light—50-250 and scattered—1-50. Another yardstick to measure the deer density at that time was the number of deer shot per man-week; it varied from 10 to 22 deer per man-week but in some South Island shooting zones up to 30 deer were killed per man-week.

Although these observations are by no means a proper census, they indicate the high densities attained by deer and probably other ungulates in their New Zealand habitat.

#### THE EFFECT ON SOILS AND VEGETATION

In New Zealand only about one-sixth of land is below 220 metres elevation and there are large areas of bleak

mountain land. Before the advent of the Maoris (14th century) by far the greatest part of the land surface (62½ million acres) was under forest. Owing to logging, burning and converting to grassland during the period of European settlement, the land under forest has now dwindled to 14½ million acres, chiefly in the high country along the main northeast-southwest axes of the two islands. Because of the youthful geological nature of the country and the structure of the rocks, normal erosion is most active in the alpine and subalpine belt, but it was held in check by subalpine vegetation and the protection forest belt. Most of the numerically important introduced ungulates live in or near these protection forests. Introduced ungulates can be clearly blamed for increased erosion only in remote areas where there is no domestic stock; in other places where farm stock are also present it is difficult to apportion the relative effect of wild and domestic animals. Areas where fire and stock were the chief agents of depletion are not included in our discussion, and animals other than ungulates are also excluded.

Some reports of the effect of introduced ungulates on soil and vegetation have been published.

MOORE and CRANWELL (1934) described the replacement of a forest formation by a grassland association without intervention of fire but dependent upon progressive action of feral goats, cattle and pigs; and TURBOTT (1948) and BAYLIS (1948) reported on the effect of goats on the vegetation of Great Island, Three Kings Group. Other observations have been made by ZOTOV et al. (1939, 1947), HOLLOWAY (1950) and ELDER (1956) on deer damage in western Southland forests and the Tararuas.

HOLLOWAY (1959) and MCKELVEY (1959) have recently reviewed their extensive work on protection forests in the South and North Islands respectively and have arrived at the following conclusions. The native vegetation of New Zealand developed in the almost complete absence of grazing and browsing animals, and there are only a few indigenous plant species which can tolerate long continued grazing and trampling; even fewer plants are both unpalatable and capable of spreading rapidly to replace those favoured by various ungulates. At high altitudes, particularly in the South Island, some of the plants that are most important for holding soil are near their altitudinal limits where consequently they are most vulnerable to animal damage. The whole picture is of great complexity—there are probably no two valleys

which would react similarly to animal use. The degradation of a forest will depend on a number of factors, climatic, geological, edaphic, and also on the animal or combination of animals present. If more than one animal is present, one or sometimes more than one, of the main components of the forest (canopy, shrub-tier and forest floor covering) may be impaired.

Students of the vegetation suggest that a population of red deer (or of any other introduced ungulate probably), finding a large supply of browse available, grows up to a peak, followed by a sharp reduction in numbers, after which deer adjust their numbers to the reduced food supply and an equilibrium may be reached. Such an adjustment of a deer population in less favourable climatic conditions was described by RINEY et al. (1959) in eastern Fiordland, but according to HOLLOWAY (1959) and MCKELVEY (1959) in other parts of New Zealand more favourable to deer, the course of events varies according to the type of forest and to the number of animals present. In beech (*Nothofagus*) forests the supply of browse is comparatively easily depleted, the « crash » occurs comparatively early and is followed by the establishment of a population at a low level. The second main type of New Zealand forest, the podocarp/mixed hardwood forest is less vulnerable because there is normally a better natural regeneration; the upward surge of animal numbers last longer, the « crash » is less noticeable but the population may establish itself at a higher level than in the beech forest. Equilibrium between the use by animals and the state of vegetation may be reached; or alternatively the vegetation may even recover temporarily, and this may lead to another increase of deer numbers towards another, though usually lower peak. The end result in either case is a markedly different forest that is less efficient as protection forest.

The impact of a given ungulate on the vegetation may become more profound and lasting in the presence of other species of grazing and browsing animals. Populations of various introduced ungulates and of the abundant Opossum (*Trichosurus vulpecula*) and Hare (*Lepus europaeus*) overlap in very many areas. The combination of these animals threatens the destruction of the forest and is upsetting the balance of its indigenous inhabitants, including the avifauna.

The competition between wild and domestic ungulates has naturally been of intense interest to New Zealand farmers, scientists and economists, which is enhanced by the possible significance of wild ungulates as

carriers of diseases to domestic animals. However, the figures available are still inadequate to show to what extent the existence of feral ungulates directly interferes with farm production. This uncertainty is increased by the fact that New Zealand has not yet reached the limits of profitable animal production on farms.

#### MANAGEMENT

*Historical.* There were two main periods in the management of the introduced ungulates in New Zealand : an initial period of protection and a later one of attempted control. In both periods prevailing interests shaped and dictated the policy.

The first period followed the liberations of the various species and lasted until about 1930. There was initially complete legal protection, and in later years partial protection—e.g. deer were shot under licences issued by the acclimatisation societies, and in later years shooting of unthrifty animals in certain deer herds was carried out by these societies.

The increasing and spreading populations of deer and other ungulates gradually began to impinge on a variety of human activities, and a growing body of the public came to realize the wide ecological and economic implications of the presence of large numbers of wild mammals. Although deep concern about the effect of introduced herbivorous animals was often expressed, particularly by biologists, from the end of the last century, it was not until the early 1920's that further deer liberations were prohibited, deer protection gradually removed and a beginning made on control of deer, subsidized mainly by means of a bonus and by supplying cheap ammunition. In 1930 protection was completely removed from deer and a bounty system, administered by the Forest Department, was inaugurated. By November 1931 however, a special Wildlife Branch of the Department of Internal Affairs, took charge of the control of deer and other introduced ungulates and organised teams to be sent every year to various districts. In 1956, by an Act of Parliament, the control of introduced ungulates became the responsibility of the Minister of Forests and was taken over by the Noxious Animals Division, N. Z. Forest Service.

Progress in the control of introduced ungulates and other widely distributed introduced mammals such as opossums (*Trichosurus vulpecula*) and wallabies (*Protemnodon* spp.) [not to mention rabbits] was not satisfactory as every year more men and finance were

required and also larger tallies were obtained. In 1955 field poisoning trials were begun, employing 1080 (sodium fluoracetate) in the hope of obtaining another and more efficient weapon against deer and other introduced mammals. This aroused a great deal of public interest and concern as the result of which a special conference of all interested bodies was called by the Minister of Forests on October 29-30, 1958. At this conference farmers, foresters, administrators, sportsmen, organisations interested in nature preservation and scientists presented evidence and gave their views on the problem of so-called « noxious animals » and the best way of dealing with them. Although there was a general agreement on the seriousness of the position, views on ways of tackling the problem differed : a minority, represented by deer-stalkers' organisations, believed that an efficient control could be entrusted to

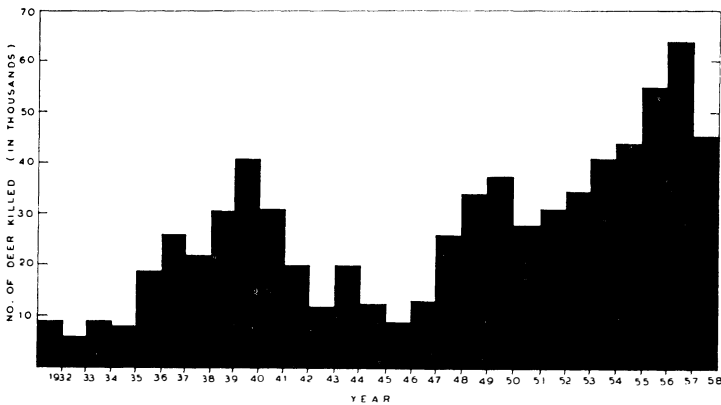


Fig. 8. — Graph showing the number of deer shot by official deer stalkers between 1932 and 1958.

sportsmen (i.e. shooters) without applying such drastic methods as deer poisoning. As a result of this conference a Government policy was formulated. This new policy aims at extermination by experimenting with methods other than shooting, by establishing various facilities such as tracks and high level huts in inaccessible country, and by working in close collaboration with private hunters through advisory committees.

*Results.* The problem of managing introduced ungulates is illustrated by Fig. 8 which shows the number of deer destroyed by Government shooters between 1932 and 1958 and by Table 1 which shows the numbers of introduced ungulates destroyed by Government sponsored operations and bounty schemes between 1951 and 1958.

The returns of red deer (Fig. 8) shot by official parties show a steady increase until the Second World War, when shortage of manpower probably caused the greatly reduced tallies. In the three years immediately after the war nearly three times the previous average was shot—probably reflecting unimpeded natural increase while control was at a minimum. In these years tallies of 40 deer per day or 2,000 per man during one summer season in the south-west part of the South Island were not exceptional. Tallies have also increased appreciably since 1951. According to R. FRASER there were between 1951 and 1958 approximately 75 men a year employed on control of introduced ungulates, especially deer (Table 1), and several factors contributed towards the higher kills. These were : (a) The development of the use of air transport for carrying men and supplies; air transport was first used in 1949-50 and doubled the shooting time and brought shooters into previously inaccessible areas; (b) The discontinuation of the recovery of deer skins by official deer stalkers in 1955, which gave more time for actual shooting; (c) The introduction in 1952-3 of an improved incentive wages scheme, based exclusively on the number of the animals destroyed. In 1958, however, the whole policy changed when it was decided to shoot deer in areas where they were doing most harm rather than where they were most numerous and this no doubt accounts for the lower returns of deer killed in 1958.

The picture for feral goats, pigs and sheep is somewhat obscured by the introduction of bounty schemes for control of these animals in certain areas. A picture similar to that of deer, of steadily increasing returns, is shown by feral goats. Pending a detailed analysis it seems that the tallies of feral sheep show no regular trend and that those of pigs tend to remain static. The position of thar is difficult to interpret, perhaps because of the sporadic control and restricted distribution of this species.

An estimate of the total number of ungulates killed annually is difficult to obtain. Since the removal of protection, there has been a growing body of people for whom deer stalking is part of their livelihood or leisure. There are no statistics but John B. HENDERSON informs me that there are at present some 5,000 organised and perhaps 10,000 unorganised, deer stalkers; he estimates the total annual bag of all these private shooters at 30,000 to 50,000 deer per annum.

Between 1932 and 1954 a total of 512,384 deer were

killed by Government hunters; from these deer 184,295 skins (i.e. 36 %) were recovered. During the same period 1,054,949 deer skins were exported. Of these at least 870,654 must have been recovered by private shooters. This would agree with Henderson's figure (660,000-1,100,000 deer) if we assume that private hunters recover the skins of all deer they shoot. If, however, the private shooters recovered about the same proportion as Government hunters, they must have killed about 2,400,000 deer, which makes Henderson's figure conservative. It seems that the total killed cannot be less than 1,400,000 deer, and could well be as high as 3,000,000.

RINEY (1956b) considered that for the first twenty years following 1932 the main effort of the official animal control work was not directed to areas critical from soil conservation, forestry or farming points of view, but mostly to those districts where deer were most numerous. By studying the relationship between the number of man-weeks and the number of deer killed per man-week in various parts of the South Island, he showed that at least in the South Island the effort expended had not at that time reached the point of diminishing returns. RINEY showed also that between 1939 and 1953 over 40 % of deer killed by official hunters came from the south-western quarter of the South Island which in the 1953-54 shooting season still yielded the largest numbers of deer per man-week.

Since that time a system of priorities has been adopted and control operations have been gradually re-directed from relatively stable areas to those considered critical in respect of soil erosion. Although this system has now been in operation for a few years, it is too early to assess its effect on the animal populations.

In Table 2 the numbers of deer, goat, chamois, thar, feral pig and sheep, and other animals killed by Government hunters between 1951 and 1958 have been expressed in terms of £1,000 expenditure. This expenditure does not include the cost of bounty schemes. Because of the changing value of money, these figures have been adjusted by means of the cost of living index so as to express them all in the purchasing power of £1,000 in 1955. Therefore to a rough approximation we may assume that the total of 777 animals killed per £1,000 in 1952 is comparable with 751 animals killed per £1,000 of effort in 1958. These figures include wallabies but the cost of their destruction could not be separated. However, as this represents only a small



fraction of the total cost (possibly 3-4 %) it should not affect the interpretation of these figures.

It is not possible to allocate the amount of money spent annually on each species but it is known that the greatest effort goes to the killing of deer. Had there been any very marked increase in the density of the deer population, one would expect a corresponding increase in the number of deer killed per £1,000. In fact the pattern of deer and goats taken separately is not very regular but taken together the numbers killed show a steady increase from 1952 to 1957. Since these two species make up the greater part of introduced ungulates killed, this trend is also visible in the totals. While it would not be advisable to draw firm conclusions from the incomplete analysis, it at least suggests that there was no decline of the populations in that period.

To sum up : the question how effective the control of deer and other introduced ungulates has been since 1932 must largely remain unanswered except that it obviously is not effective enough. To provide a full answer much more basic information is required. This information should include at least : (a) an assessment of population density which in turn necessitates the development of suitable methods; (b) information on the operation of natural control in relation to population growth of deer and of other species of wild and feral mammals. The work has already begun, as evidenced by recent papers by botanists (HOLLOWAY, 1950 and 1959, HOLLOWAY and NAYLOR, 1959; MCKELVEY, 1959) and zoologists (RINEY *et al.* 1959, RINEY and CAUGHLEY, 1959). As mentioned in the preamble the complex nature of the country makes the solution of New Zealand's wildlife problems an extremely difficult task. At the same time it provides an immense scope and a challenge to the workers in this field.

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## SUMMARY

Some fifteen species of ungulates are established in a wild or feral state in New Zealand: red deer (*Cervus elaphus*), fallow deer (*Dama dama*), Japanese or sika deer (*C. nippon*), Sambardeer (*C. unicolor*), Javan rusa deer (*C. timoriensis*), wapiti (*C. canadensis*), Virginia or white-tailed deer (*Odocoileus virginianus*), moose (*Alces alces*), chamois (*Rupicapra rupicapra*), thar (*Hemitragus jemlahicus*), feral goat, pig, horse, cattle and sheep. For each of these species an account is here given of the liberation, spread since 1948, and present distribution.

Some species (e.g. moose and sambar) are still confined to the vicinity of their original points of liberation, but other species (e.g. red deer and chamois) have spread into a variety of habitats and are still increasing in range and numbers.

Information is presented on the effects of various ungulates on soils and vegetation. These effects are more serious in the beech (*Nothofagus*) forests than in the podocarp/mixed hardwood forests because in the latter type, with more plant species available and better natural regeneration, an equilibrium is reached more gradually and at an earlier stage of depletion of vegetation. A combination of two or more ungulate species accelerates the rate of change. The end result in any case is a markedly different plant cover that protects the soil less efficiently.

A brief history of the management of these ungulates is given and the methods, organisation and results of control are described. Of deer, for instance, over half a million were killed by Government hunters alone between 1932 and 1954, and the total number shot during that period cannot be less than 1,400,000 and could be as high as 3,000,000. A statistical analysis of the number of wild and feral ungulates destroyed between 1951 and 1958 suggests that there was no significant decline of the populations during that period.

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TABLE 1  
 RETURNS OF INTRODUCED UNGULATES KILLED  
 BY OFFICIAL SHOOTERS OR BY PRIVATE SHOOTERS UNDER  
 BOUNTY SCHEMES DURING 1951-1958

Year ending 31st March	Deer	Goat	Pig	Chamois	Thar	Feral Sheep	Other Species	Grand Total	Cost
1951 .....	28,192	27,356	26,641	2,611	821	2,439	3,474	91,534	£55,861
1952 .....	30,913	27,296	28,641	1,267	160	2,169	1,880	92,326	£70,655
1953 .....	34,514	32,855	30,265	1,504	45	900	69	100,152	£79,721
1954 .....	41,030	33,475	30,659	1,533	446	2,339	238	109,720	£77,855
1955 .....	44,418	29,050	21,353	2,443	2,716	1,498	166	101,644	£81,345
1956 .....	55,305	51,939	27,288	3,724	585	1,702	331	140,874	£115,375
1957 .....	63,828	69,420	24,578	4,837	616	2,274	201	165,754	£136,652
1958 .....	45,730	60,730	22,957	3,964	494	2,366	364	136,605	£130,161
TOTAL ....	343,930	*332,121	**212,382	21,883	5,883	***15,687	6,723	938,609	£747,625

\* 53 % by private shooters working under bounty schemes  
 \*\* 90 % » » » » » » »  
 \*\*\* 49 % » » » » » » »

TABLE 2  
ANIMALS KILLED PER £1,000 EXPENDITURE

Year	Deer	Goat	Chamois	Thar	Feral Pig	Feral Sheep	Other Species	Total
1951 .....	454	172	42	13	30	10	56	777
1952 .....	416	159	17	2	16	5	25	640
1953 .....	428	210	19	1	19	3	1	681
1954 .....	553	163	21	6	22	15	3	783
1955 .....	573	162	32	35	35	14	2	853
1956 .....	519	255	35	6	37	11	3	866
1957 .....	518	302	39	5	33	12	2	911
1958 .....	404	253	36	4	35	16	3	751