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# PRESIDENTIAL ADDRESS: JOHN PARKES

**John Parkes** *was born in Marton, went to school in New Plymouth, and completed his BSc and MSc degrees at Massey University. He joined the Forest Research Institute at Ilam as a scientist in* 1975 *and transferred to Landcare Research when the Crown Research Institutes were formed in* 1992. *John has worked on the ecology of many mammals (hedgehogs, possums, swamp wallabies, hares, red deer, wapiti, feral goats, Himalayan thar, and chamois). John's present research is aimed at understanding the nature of impacts of controlled populations of feral goats and possums in forest ecosystems to determine control intensities and frequencies needed to protect forest values. However, understanding the biology of pest-resource systems has not, by itself, led to sustainable protection of resources, and since* 1987, *John has been involved with developing national pest control plans in New Zealand for the Department of Conservation and in Australia for the Bureau of Resource Sciences. The aim of these national plans has been to identify and integrate the "best practice" legal, policy, strategic, tactical, and economic elements of pest management, and to ensure they are put into practice to maximise the benefits to the resources of value. John has published 30 papers and produced numerous reports for pest management agencies. He joined the Ecological Society in* 1975 *and has served on Council and as Secretary, Vice-President, and President.*

# FERAL GOATS: DESIGNING SOLUTIONS FOR A DESIGNER PEST

**Summary:** The ability of feral goats to become pests is partly a consequence of the process of domestication. Neolithic people selected biological characteristics from wild goats, such as higher intrinsic rates of increase and increased sociability that have resulted in their domestic descendants becoming a particular nuisance when they escape to become feral. Feral goats live in about 11 % of New Zealand, mostly on land reserved for conservation of the indigenous biota. Their uncontrolled densities are usually less than 1 $ha^{-1}$, but have reached 10 $ha^{-1}$ in one area. The total population is estimated to be at least 300000, which makes them the most common free-living ungulate in New Zealand. Most populations breed throughout the year, but show distinct peaks of activity in summer and for some populations again in early winter. Most populations show a distinct decline in breeding in late autumn to mid spring. Annual birth rates can be high, up to 1.42 kids per female in the study populations. This is achieved by breeding twice within the year, breeding at an early age (as young as 6 months), and often producing twins and triplets. Feral goats are highly selective in what they eat, but have the ability to switch their diets as the more palatable food species are eliminated from their habitat. All these characteristics make goats particularly problematic pests on the conservation estate. However, domestication did not turn the goat into a complete r-strategist, boom-bust pest. Unharvested feral populations in New Zealand form dynamic K-strategist relationships with their resources that are stable, at least in the short term. This means their impacts are chronic, but the relationship can be manipulated to favour the resource if management can be applied "chronically", i.e., as sustained control. The Department of Conservation has attempted to organise its control actions in the highest priority areas either to eradicate goats where possible or to sustain control where eradication is not presently possible. An annual budget of $3.8 million was tagged for goat control in 1990-91. Since then, the Department has acted against goats in 146 areas, and successfully eradicated 14 populations. In 1992-93, 6160 hunter-days of ground control effort, and 230 hours of helicopter hunting effort were expended against feral goats, and 10.2 km of goat fencing was constructed. The effort was similar in 1991-92, and larger in 1990-91. The Department is attempting to ensure their control effort is maximised and sustained via a formal national control plan, and regional Conservation Management Strategies. If the present effort is maintained over the next decade, about half the feral goat populations now on the conservation estate are expected to be eradicated or controlled.

**Keywords:** Feral goat; *Capra hircus;* pests; population densities; breeding; diet; control; management; impacts.

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# Introduction

Domestic goats *(Capra hircus* L.) have escaped and established feral populations on many occasions since they were first brought to New Zealand in 1773 (Beaglehole, 1961). The first recorded large-scale attempts to control unwanted feral goats were conducted early this century by sheep farmers in the Shotover River catchment (Thomson, 1922), an area that still has substantial feral populations. Nationally coordinated efforts to control ungulate pests began in 1930 when the Department of Internal Affairs began organised culling campaigns (Miers, 1985). Initially, these campaigns focused on red deer *(Cervus elaphus scoticus* Lonnberg) and concentrated on areas with the highest animal densities through a policy of extermination. This policy failed. It was replaced by a system that identified priority catchments (generally based on perceived threats to downsteam water and soil values) and included other pests such as goats (Riney, 1956). Feral goat control became an increasing part of central government actions after 1956, the year in which control of vertebrate pests on the conservation estate was passed to the New Zealand Forest Service. This was partly because the rationale for ungulate control changed from one of killing pests to one of protecting resources, and partly because from the 1960s commercial harvesting for game meat was achieving major reductions in deer and Himalayan thar *(Hemitragus jemlahicus* Smith) populations (Challies, 1985).

The variety of reasons used by the Forest Service to justify goat control included protection of indigenous biota and ecosystems, on-site and downstream protection of water and soil values, protection of urban water supplies, competition with domestic stock, and protection of plantation forests. Whatever the reason, or its validity, many of these operations successfully protected values now of concern to the Department of Conservation.

In 1987, responsibility for control of feral goats (under the Wild Animal Control Act) passed from the Forest Service to the newly formed Department of Conservation (DoC). The Department's reasons for controlling feral goats were redefined in its principal act, the Conservation Act 1987, to place a greater emphasis on protection of indigenous biota and ecosystems than previously. Despite inheriting some successes, the Department also faced increasing problems from feral goats after a short-lived enthusiasm for redomestication of goats led to the establishment of many new feral herds in the late 1980s (Parkes, 1994, *unpubl. Landcare Research contract report).* In response to the public concern this caused, government allocated additional funds ($3.8 million) to the Department in 1990 to control goats. Since 1990, the Department has rationalised its control operations to spend this tagged money within a National Feral Goat Control Plan (Parkes, 1994, *unpubl. Landcare Research contract report).*

The difficulty in managing goats' impacts on the indigenous biota is exacerbated by the biological characteristics of feral goats, some of which have been induced by the process of domestication. Humans "designed" goats with characteristics that were useful for domestic animals but make feral animals particularly effective pests. This paper details these biological characteristics and then describes how DoC must design control solutions at legal, policy, strategic, and tactical levels to take account of the biology of feral goats, the way they affect natural resources, and the nature and relative importance of these natural resources, with the aim of maximising the conservation benefits from actions against feral goats.

# Methods

This paper uses the licence of a Presidential address to mix relevant published information, and information from several of my unpublished reports on feral goats commissioned by DoC, with some unpublished data of my own.

**Reproduction**

Female goats were autopsied by hunters during control operations carried out at various times between 1982 and 1990 on Raoul Island (n = 343), in Waipoua Forest Sanctuary (n = 146), the Te Paparahi area of Great Barrier Island (n = 159), the Kaimai Conservation Park (n = 78), the Maratoto and Puriri areas in the southern Coromandel Conservation Park (n = 394), the Raukumara Range (n = 857), Pirongia Conservation Park (n = 328), Mt Egmont National Park (n = 477), the Seaward Kaikoura Range (n = 923), and the Shotover River catchment (n = 1032). The latter five areas were sampled over a whole year. Attempts were made to avoid biases in selecting which females were autopsied by sampling all accessible animals, all those shot on certain days, or the first few shot each day. The reproductive state (pregnant, lactating, or both) and the number, body length, and sex of any embryos were recorded. One-half of the lower jaw of each goat was removed and the animal referred to one of 11 age classes based on the eruption and

replacement of milk teeth or the amount of tooth wear in full-mouthed adults (Parkes, 1984a). Differences between the five estimates of fecundity were tested by ANOVA with paired comparisons being made using LSD tests.

Breeding seasons for the five populations sampled throughout a year were delineated from the monthly frequencies of conceptions. These were calculated from an embryo length - age curve (Parkes, 1984a) derived from data given by Harrison (1948) and Eaton (1952). The observed monthly frequencies reflect both real breeding seasonality and the sample sizes over the following months. The effect of different monthly sample sizes has been eliminated by using $X^2$ tests to compare the observed frequencies of conceptions with frequencies expected if there was no breeding season, weighted for each month by the number of females of breeding age sampled over a following period equal to the measured observable gestation period. This was taken for each sample as being 150 days (Peaker, 1978) less the age of the smallest embryo reported by the hunters - usually embryos < 1 or 2 cm long (< 30 days old) were not found.

$$\text{Expected frequency} = C \times \Sigma F / \Sigma\Sigma F$$

where C = total number of conceptions in the sample;

$\Sigma F$ = the "catchment" sample size, i.e., the number of females of breeding age sampled between the first sampling date of the month plus the age of the smallest recorded embryo and the last sampling date of the month plus 150 days;

$\Sigma\Sigma F$ = the sum of each monthly "catchment" sample sizes.

Birth rates were estimated for each sampled population by summing fecundities of the nine age classes of breeding age (i.e., older than 6 months), each weighted by its proportion in the sample. Goats simultaneously pregnant and lactating were assumed to have bred twice within the year.

**Diet**

Twenty goats were shot in summer 1985 from two adjacent populations on either side of the Motu River. Rumen samples from each were sieved through a 4 mm grid, and the larger fraction was sorted into plant species, each of which was dried and weighed. Differences in the diets of the two populations were tested using rank sum tests.

**Hunting statistics**

The ground and aerial hunting effort and numbers of goats killed during all DoC goat control operations in 1992-93 were collated.

# Results

**Characteristics of wild goats**

The wild goat *(Capra aegagrus* Erxleben) now exists as taxonomically ill-defined races or sub-species in Turkey and Iran (*C. a. aegagrus* - the Bezoar goat), and from Turkmenia to Pakistan (c. *a. blythi* Hume - the Sind ibex) (Schaller, 1977). Their demographic status is uncertain as human activities encroach on their range. The breeding season (= conceptions) in wild goats occurs over a narrow period of a few weeks. However, there appears to be some flexibility in the timing of the rut between populations and between years within populations. In the Himalaya, it occurs over a few weeks between late July and early October (Le., late summer to early autumn), depending on the year (Roberts, 1967; Schaller 1977), but in the Caucasus, wild goats rut during November and December (Couturier, 1962). The first kids' of Sind ibex in Kirthar National Park in Pakistan were seen in mid-January, and more than 75% were born in the first weeks of February with occasional births as late as April (Le., a core breeding season in October) (Edge and Olson-Edge, 1990).

There are no reports of wild goats breeding twice within a year. Females do not become pregnant until they reach their second year, and most not until they are 3 years old (Schaller, 1977). Single young are the rule in most years, but twins and more rarely triplets have been reported (Wahby, 1931 ; Edge and Olson-Edge, 1990).

**Domestication**

Goats were domesticated about 9000 years ago (Clutton-Brock, 1992). This involved both a cultural process whereby goats were integrated into human society as property (Ducos, 1989), and a biological process in which the human owners applied selection pressures favouring characteristics such as short flight distances and sociability (for ease of herding), wide dietary preferences (so the goats and their owners were not restricted to one habitat), variable coat colours (perhaps so that owners could recognise individuals), and high productivity. High productivity is attained by early sexual maturity, extended breeding seasons, the ability to become pregnant while still lactating, and by producing

more than one offspring per pregnancy - all desirable characteristics in a domestic animal. With the exception of coat colour, it is exactly these r-strategist characters that make domestic goats such serious and resilient pests when they revert to a feral state.

**Distribution and density of feral goats in New Zealand**

The impact of goats is enhanced because their sociable nature allows high densities in favoured habitats. Feral goats occupy about 30 000 $km^2$ (11 %) of New Zealand, of which about 20 000 $km^2$ is land managed by DoC (about 37% of the total area administered by the Department), including seven islands (Great Barrier, Waiheke, Rakitu, Kaikoura, Pourewa, Forsyth, and Arapawa). Domestic or semi-domestic goats are present on several other islands (e.g., Chatham, D'Urville). Unlike some near-ubiquitous pest species such as possums *(Trichosurus vulpecula* Kerr), goats are patchily distributed on habitat "islands" in the North and South Islands. This patchiness allows managers to consider eradication as an option for some mainland populations, as has been achieved on 17 islands - those listed in Veitch and Bell (1990) plus Auckland Island.

Densities of feral goats in New Zealand vary considerably (Table 1). Densities at carrying capacity varied from 0.04 to 10 goats $ha^{-1}$ on islands, and appeared to rarely exceed 0.3 goats $ha^{-1}$ in mainland areas.

It is difficult to estimate the national population size of feral goats, but it is likely to be at least 300000 (an average density of 0.1 goats $ha^{-1}$ ). However, it could be as high as 1 000000 if densities in areas where goats are not controlled are as high as those on Raoul Island in 1971, before intensive hunting of this population began from 1972 until 1984 (Parkes, 1984a). Kirton and Ritchie (1982) estimated a national feral herd of about 400 000. Large numbers of goats that are often indistinguishable from ferals are also held on private land, usually to control weeds. There were 1.3 million domestic goats in New Zealand in 1988 (New Zealand Yearbook, 1990) that would include many of these unimproved herds. About 200 000 goats are mustered and slaughtered annually at about 19 abattoirs (K. Armstrong, MAF Qual, *pers. comm).*

To put these estimates into perspective, feral goats are probably the most common wild ungulate in New Zealand. The national population of feral pigs may be several hundred thousand as an estimated 100 000 are harvested annually (Nugent, 1992). The number of wild deer (mostly red deer) is about 250 000 (Nugent and Fraser, 1993), and of thar about 14000 (Parkes, *in press).* However, these species are held by past and present hunting at densities well below their carrying capacities, although thar at least are increasing (Parkes, *in press).*

**High potential productivity**

Feral goats have retained the r-strategist characteristics of their domestic ancestors that allow for high productivity. They also retain the wild goat's short gestation of 150 days but have a new ability to become pregnant while still lactating, so producing a second litter within a year. Females can become pregnant when as young as 6 months old, and twins and triplets are common.

*Breeding seasons*

Modem domestic goats can breed over a much longer season than their wild ancestors, with tropical breeds such as the Creole goat breeding year-round and temperate breeds such as the Alpine goat being sexually quiescent during about 4 months from early summer (Levasseur and Thibault, 1980).

Most of the five New Zealand populations I studied year-round showed some breeding (= conceptions) throughout the year, but with distinct peaks of activity in summer (December - February), in all five populations, and in early winter (June - July) in the Raukumara, Pirongia, and Kaikoura populations. All populations except the Shotover showed a significant decline in breeding activity at some time between late winter (August) and mid-spring (November) (Fig. 1).

*Fecundity*

The number of embryos produced per female of breeding age among the five populations with year-round sampling varied from 0.90 to 1.42 (Table 2), the differences being significant ($F = 10.55$, $P < 0.01$). The Raukumara sample produced significantly fewer *(*$P = 0.05$) embryos than the Shotover, Egmont, and Kaikoura samples; the Pirongia sample produced significantly fewer than the Egmont and Kaikoura goats; and the Shotover goats produced significantly fewer than the Egmont and Kaikoura goats. These differences reflected the length and intensity of control operations. Populations that experience extensive control have lower densities and more food *per capita,* resulting in higher fecundities. This increase in fecundity occurred on Raoul Island, where the average increased from 0.94 to 1.71 kids per annum as goat densities were reduced from 1970 until they were eradicated in 1984 (Parkes, 1990b).

Table 1. *Estimated densities of feral goats at specific times in various areas in New Zealand. Actual densities are given for Macauley and Cuvier Islands where the entire populations were shot.*

| Location | Area (ha) | Habitat | Past hunting intensity | Goats ha$^{-1}$ | Year of estimate | Reference |
|---|---|---|---|---|---|---|
| Macauley Island (Kermadecs) | 320 | Grass | none | 10.0 | 1966 | Williams and Rudge (1969) |
| Cuvier Island | 100 | Forest | none | 3.3 | 1970 | Merton (1970) |
| Raoul Island (Kermadecs) | 2950 | Forest | low | 1.0 | 1971 | Parkes (l984a) |
| Te Paparahi (Great Barrier Is.) | 4000 | Forest | low | 0.3 | 1986 | Parkes (1990a) |
| Dinner Creek (Waima River) | 638 | Forest/grass | moderate | 0.17 | 1992 | Brennan. Moller and Parkes (1993) |
| Mt Egmont National Park | 30000 | Forest | high | 0.1 | 1990 | Parkes (l990a) |
| West Motu River (Raukumara Ra.) | 5000 | Forest | low | 0.1 | 1982 | Parkes (1983) |
| Wairau (Marlborough) | 112000 | Forest/grass | high | 0.05 | 1973 | Bathgate (1973. *unpubl. report)* |
| part of Auckland Island | 4000 | Forest/grass | none | 0.04 | 1989 | Sherley (1988) |

Table 2. *Annual production of kids* in *five feral goat populations sampled over a complete year. It* is *assumed intra-uterine mortality of embryos* is *zero.*

| Population | No. embryos adult female$^{-1}$ year$^{-1}$ ± SE | Population control history |
|---|---|---|
| Kaikoura | 1.42 + 0.07 | Intensive control for many years Intensive |
| Egmont | 1.40 + 0.09 | control, density now about 10% of carrying capacity |
| Shotover | 1.14 + 0.06 | Recent intensive control Fluctuating past |
| Pirongia | 1.12 + 0.09 | control |
| Raukumara | 0.90 + 0.05 | Sampled at start of control campaign |

Table 3. *Reproductive patterns by age class among 4390 female feral goats.* (*m = milk tooth, e = erupting tooth. P = adult tooth, - = not erupted). Ages in months are after Habermehl (1961). Full-mouth adults were divided into* 3 *age classes depending on the degree of tooth wear. M = male. F = female.*

| Tooth pattern | Age class (months) | N | % pregnant | % lactating | % pregnant and lactating | Mean no. embryos | Embryos 100 females$^{-1}$ yr$^{-1}$ | Primary sex ratio M:F |
|---|---|---|---|---|---|---|---|---|
| mmm m mmm - | 0-4 | 394 | 0 | 0 | 0 | 0 | 0 | - |
| mmm m mmm e- | 5 | 105 | 0 | 0 | 0 | 0 | 0 | - |
| mmm m mmm P- | 6 | 539 | 24.1 | 6.7 | 3.5 | 1.17 | 44.2 | 1.00 |
| mmm m mmm Pe- | 7 | 218 | 27.5 | 22.5 | 4.6 | 1.19 | 70.2 | 1.04 |
| mmm m mmm PP- | 8 - 12 | 398 | 29.1 | 31.4 | 6.5 | 1.38 | 101.6 | 1.07 |
| Pmm m mmm PP- | 13 - 16 | 431 | 33.4 | 40.1 | 8.4 | 1.30 | 123.4 | 1.07 |
| PPm m PPP PP- | 17 - 22 | 295 | 33.6 | 52.9 | 12.5 | 1.35 | 150.9 | 0.97 |
| PPP m PPP PPP | 23 - 26 | 609 | 31.5 | 38.4 | 14.0 | 1.56 | 152.3 | 0.73 |
| Full mouth, no wear | >26 | 683 | 34.6 | 38.9 | 11.3 | 1.56 | 149.4 | 0.97 |
| Full mouth, some wear | >26 | 517 | 25.3 | 43.3 | 14.3 | 1.58 | 153.3 | 1.04 |
| Full mouth, much wear | >26 | 210 | 20.9 | 44.3 | 10.4 | 1.49 | 128.4 | 1.58 |

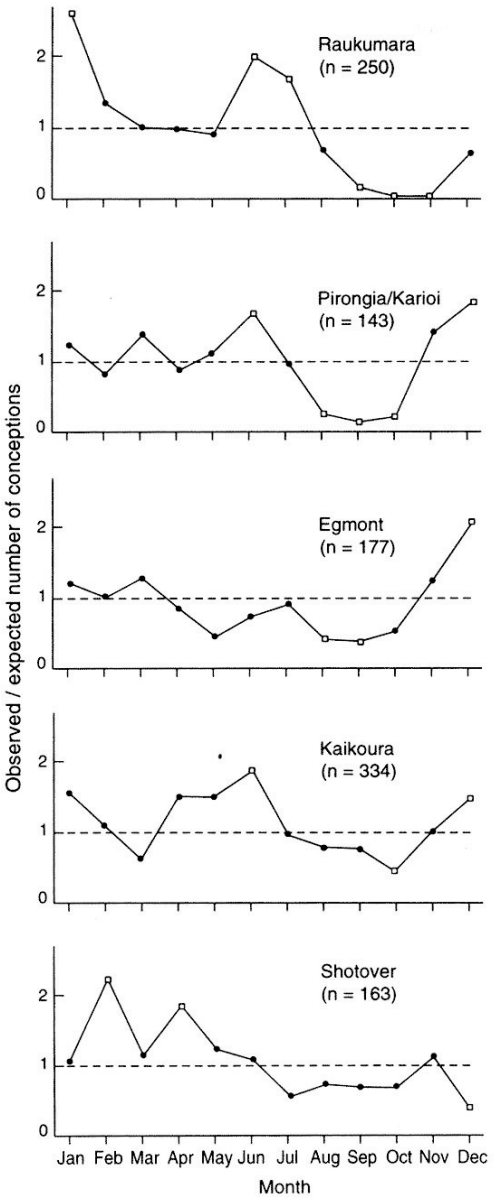


Figure 1. *Observed/expected monthly number of conceptions in five feral goat populations. Months where significantly more or less conceptions occurred than would be expected if there was no defined breeding season are marked _. The ratio would be 1 if goats bred at any time of year.*

The pattern of reproduction across age classes was similar in all populations sampled. A small proportion of females bred when less than 1 year old, but they rarely produced more than one kid and rarely conceived again while nursing their first offspring (Table 3). Their overall contribution to the population's productivity was low. The proportion pregnant, lactating, or both, and the number of embryos increased with maternal age, reaching a maximum in goats about 3 years old, and then declining in the oldest age class (Table 3).

### *Intrinsic rate of increase*

The intrinsic rate of increase has not been estimated for any feral goat population, either by repeated annual censuses after control or by estimation from a life table and fecundity rates. Some limited evidence (Rudge and Smit, 1970) gave a natural exponential mortality rate for one population as 0.105. Assuming the birth rate measured by Parkes (1984a) for Raoul Island (b = 0.618) is the maximum and the mortality rate estimated by Rudge and Smit (1970) for the Rimutaka population (d = 0.105) is the minimum, the intrinsic rate of increase would be 0.513. A population of goats with such a high rate of increase would double in 17 months if hunting mortality ceased.

## Impact on indigenous plants

Goats are generalist browsers of shrubs and trees rather than grazers of grass (Bullock, 1985), and contrary to popular opinion they have strong dietary preferences. In New Zealand, where water availability is unlikely to limit their numbers, goat populations that are not subjected to control or mustering appear to remain stable. This suggests goats behave like other introduced ungulates (e.g., Caughley, 1970) and form a dynamic equilibrium with their food supply.

On Raoul Island 51 % of goats' diet was pohutukawa *(Metrosideros kermadecensis)*[1] , tutu *Coriaria arborea),* and fungus *(Auricularia* spp.) (Parkes, 1984b). On Mt Taranaki, 51 % of their diet was hen and chicken fern *(Asplenium bulbiferum),* supplejack *(Ripogonum scandens),* and kamahi *(Weinmannia racemosa)* (Mitchell, Fordham and John, 1987). Other preferred species include mahoe *(Melicytus ramiflorus),* broadleaf *(Griselinia littoralis),* and most large-leaved *Coprosma* spp.

Goats have reduced several insular plant species to the verge of extinction, with the

[1] Botanical nomenclature follows Allan (1961), Moore and Edgar (1970), and Connor and Edgar (1987).

Table 4. *Differences in main dietary items by weight (wt) of feral goats from adjacent populations with short (east bank) and long (west bank) histories of occupation*.

| Food item/species | East bank Mean % of sample dried wt. | West bank Mean % of sample dried wt. | Difference *(P)* |
|---|---|---|---|
| **More in east bank diet** | | | |
| *Coprosma* spp. | 8.6 | 3.0 | 0.01 |
| *Carpodetus serratus* | 7.3 | 1.0 | 0.01 |
| *Clematis parviflora* | 5.5 | 1.0 | 0.01 |
| epiphytic *Asplenium* spp. | 2.7 | 0.7 | 0.05 |
| *Hebe salicifolia* | 2.6 | 0.3 | 0.05 |
| *Lotus pedunculatus* | 2.2 | 0.1 | 0.05 |
| *Myrsine australis* | 1.7 | 0.1 | 0.05 |
| *Asplenium bulbiferum* | 1.2 | 0.1 | 0.05 |
| *Phymatosorus diversifolius* | 0.8 | 0.2 | 0.05 |
| **More in west bank diet** | | | |
| *Ripogonum scandens* | 14.8 | 26.1 | 0.05 |
| *Weinmannia racemosa* | 2.0 | 10.0 | 0.05 |
| *Dicksonia squarrosa* | 0.2 | 2.4 | 0.01 |
| *Blechnum* spp. | 0.2 | 0.9 | 0.05 |
| *Griselinia littoralis* | 0.1 | 1.0 | 0.05 |
| *Metrosideros diffusa* | 0.1 | 0.6 | 0.001 |
| *Auricularia polytricha* | 0.0 | 6.3 | 0.001 |
| **No difference** | | | |
| *Melicytus ramiflorus* | 9.0 | 11.7 | NS |
| *Coriaria arborea* | 3.3 | 0.4 | NS |
| *Libertia ixioides* | 2.9 | 0.7 | NS |
| *Geniostoma ligustrifolium* | 2.3 | 0.6 | NS |
| *Cirsium vulgaris* | 1.8 | 4.3 | NS |
| *Pseudopanax* spp. | 1.8 | 0.1 | NS |
| *Olearia rani* | 1.5 | 1.5 | NS |
| *Fuchsia excorticata* | 1.0 | 0.1 | NS |
| *Ixerba brexioides* | 0.6 | 8.0 | NS |
| *Schefflera digitata* | 0.5 | 1.1 | NS |

Table 5. *Areas from which feral goats have been eradicated from mainland areas by DoC's control efforts between 1990 and June* 1993. *Note: some ongoing costs may be needed to verify these claims of success. Some operations (marked *) began prior to 1990. SR = Scenic Reserve; NP = National Park.*

| Operational area | DoC Conservancy | Area (ha) | Total effort (hunter-days) | Goats killed since 1990 |
|---|---|---|---|---|
| Te Paki | Northland | 500 | 51 | 61 |
| West Rotoehu | Bay of Plenty | 150 | 7 | 66 |
| part Te Kopia SR | Bay of Plenty | < 2 500 | 29 | 52 |
| Mokomokonui | Bay of Plenty | 300 | ? | 88 |
| part W. Urewera* | East Coast | 2 000 | 51 | 51 |
| part Tongariro NP* | Tongariro/Taupo | 300 | 9 | 49 |
| Okama SR | Tongariro/Taupo | 70 | 8 | 43 |
| Omori SR | Tongariro/Taupo | 30 | 2 | 13 |
| GracesIMorunga SR | Tongariro/Taupo | 150 | 6 | 12 |
| part NW Ruahine* | Hawke's Bay | 2 400 | 396 | 238 |
| part Otira | West Coast | 2 700 | 95 | 15 |
| Lake Kaniere SR | West Coast | 2 000 | 9 | 1 |
| part DeanIRowallan | Southland | 3 000 | 8 | 49 |
| Neale Bum* | Southland | 2 000 | ? | 1 |

Kermadec hebe *(Hebe breviracemosa)* on Raoul Island (Parkes, 1984b) and *Tecomanthe speciosa* on Great Island (Williams and Given, 1981) apparently being reduced to single plants.

Goats can also alter the character of forests, especially where the palatable species are also the dominant canopy trees, by stopping regeneration of the more palatable species. The most convincing evidence of these changes comes from studies where goats have been eradicated from islands (e.g., from Great Island in the Three Kings group; Holdsworth, 1951), or excluded from plots (Parkes, 1990a; Blaschke, 1992, *unpubl. DSIR contract report)*. In the latter experiments the lack of regeneration of palatable plants outside the fenced plot compared with the flush of growth inside the exclosure is evidence of the impact of goats. Control of goats may permit forest structures to be restored to a large extent if the main palatable understorey plants are those of canopy species (e.g., beech *(Nothofagus* spp.), mahoe, rata *(Metrosideros* spp.), and kamahi), and they are not simultanously attacked by possums. However, it is likely that some plants that never exceed goat-browse height may be driven to local extinction, or survive only as epiphytes or in inaccessible places. There is some evidence that this has occurred in the Raukumara Range (J. Parkes, *unpubl. data)*. Feral goats have been the only ungulate present for at least 50 years on the west bank of the Motu River, but (along with red deer) only recently on the east bank. It can be assumed that the pristine forests on either bank were similar as they exist on similar topography and geology (Kingma, 1975), and the present mosaic of canopy types is the same (Nicholls, 1971). The diet of the newly-colonised goat population on the east bank should represent the most preferred species, and any of these not present in the diet of the long-established population on the west bank would be circumstantial evidence that this species had been eliminated or reduced to inaccessible sites.

The diets of the east and west bank populations showed significant differences (Table 4). Recently-established goats on the east bank ate more understorey species and herbs, but those on the west bank ate more species of plants that form the canopy, such as kamahi. Highly preferred canopy species such as mahoe remained similar in both diets, presumably because of the availability of fallen foliage and of epicormic shoots.

The presence of some plant species appears to be goat-induced, such as the fungus *Auricularia*. It is a favoured food (Parkes 1984b), forming 6% of the diet of west bank goats but is absent from the east bank. This might be an indication of dead wood induced by browsing. In other areas, dominance of the grass, *Microlaena avenacea,* has been blamed on browsing by goats and other ungulates (Moore and Cranwell, 1934).

## Designing control solutions

### *Legal solutions*

Feral goats are defined as pests by implication in the Conservation Act 1987. This obliges Government, through DoC, to preserve and protect natural resources with intrinsic values. The intrinsic values of indigenous flora and fauna, ecosystems, and landscapes are stressed in the Conservation Law Reform Act 1990, and defined in relation to ecosystems in the Resource Management Act 1991 as "those aspects of ecosystems and their constituent parts which have value in their own right ..". In application, intrinsic values are the characteristics ascribed to species (e.g., rare, endemic, distinct), ecosystems (e.g., representative, diverse), or processes (e.g., stable, dynamic).

Feral goats in the wild in New Zealand ate natural resources but almost always without intrinsic values and are therefore pests because they adversely affect natural resources that do have intrinsic values. This definition is reinforced by tenure-specific acts such as the National Park Act 1980 and the Reserves Act 1977, which require introduced species such as goats to be removed (as far as possible) from National Parks and Reserves. Rarely, feral goats may have some value in their own right where isolated populations may retain some unique characters, e.g., those on Arapawa Island (Rudge, 1984).

How goats may be controlled is defined by the Wild Animal Control Act 1977. Goats had a complex legal definition under the original act, which created difficulties for land managers wishing to take action against animals whose ownership or status was in doubt. Government proposes to amend the Wild Animal Control Act to define any goat on any land a wild animal unless it is effectively restrained and is branded. Wild animals may be hunted or controlled by DoC or by anyone with the consent of the landowner.

### *Policy solutions*

Legal solutions by themselves do not lead to effective pest control, as evidenced by the numerous species defined as pests by the above legislation but for which little or no control is undertaken (e.g., rats, mustelids). Policies aim to put legislation into practice, and so they need to take account of the political, management,

technical, and financial constraints of pest management. The Department of Conservation's policies on feral goats are determined by a Draft National Feral Goat Control Plan (Parkes, 1994, *unpubl. Landcare Research contract report),* which determines that goats are manageable pests and allocates an annual budget specifically tagged by Government for control of goat populations defined as having high priority over the next decade.

*Strategic solutions*

There are three basic strategic options to manage feral goats:

Where a single management action results in a permanent benefit. This option includes actions to ensure no new goat populations are established, or present populations are eradicated. For other pests, biological control or habitat manipulation can be included in this strategy, but these are not options for goat control because any disease would also affect domestic goats and habitat manipulation capable of affecting goats would destroy the very values managers are trying to protect.

Where some ongoing action is required to maintain the benefit. For goat control, this generally means sustained annual control by DoC-employed hunters, but for other pests commercial or recreational harvesting can sometimes achieve conservation goals (Nugent and Fraser, 1993).

Where no action is justified or possible and nature is left to take its course.

Feral goats have been eradicated from many islands (Coblentz, 1978; Veitch and Bell, 1990; Parkes, 1990b). As their mainland distribution is often patchy, the patches may be treated as habitat islands and the goats eradicated under certain conditions (Parkes, 1990b; Bomford and O'Brien, 1992). The conditions necessary for eradication attempts to be successful are that immigration must be zero (otherwise the best one could achieve is zero density and a sustained effort to kill immigrants), the goats must be killed at a rate exceeding their rate of increase at all densities, and all goats must be at risk. There are some additional but non-critical conditions that improve the chance of success in eradication operations. It helps if those attempting the task believe it is possible (e.g., eradication of goats on Raoul Island - Parkes, 1990b), or if something is known about the biology of the pest (e.g., an understanding of goats' dispersal using radio-telemetered Judas animals is assisting in their control in Otago - Hondelink, 1992, *unpubl. Otago Conservancy report).*

The critical conditions for eradication are seldom met, usually because of immigration of escaped domestic goats, so sustained control is the usual strategy by which feral goats are managed in New Zealand. This involves reducing the population to some density at which their impact is tolerable (the target density), then harvesting the annual increment to maintain this state. The target densities for goats in forests are low, and the rate of increase of goats is high, resulting in the need for frequent (generally annual) maintenance control.

*Tactical solutions*

Successful control of feral goats is rarely limited by the lack of suitable control technologies. Skilled hunters usually with trained dogs to find and hold the goats are the most commonly used method, especially in forested habitats. Goats have been greatly reduced, temporarily removed, or even eradicated from many areas of forests using ground hunters (Parkes, 1990a). In 68 control operations conducted by DoC in the North Island since 1990, hunters covered an average 71.3:t 17.5 ha (range 6 to 370 ha) per day.

More specialised control methods are also commonly used. Aerial hunting from helicopters has been especially effective in controlling low-density populations in forested habitats (by targeting goat-favoured slips and clearings) and high-density populations in grassland/scrub habitats. More recently, the use of radio-telemetered

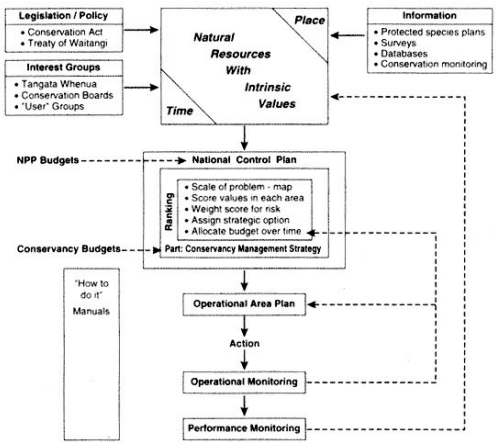


Figure 2. *A national planning structure to manage feral goats on the conservation estate.*

Judas goats to locate remnant groups has proved successful (Hondelink, 1992, *unpubl. Otago Conservancy report)*.

Poisoning natural vegetation baits with 1080 (sodium monofluoroacetate) mixed in gel or grease carriers has reduced goat populations by over 90% in some experiments (Parkes 1983). However, attempts to develop a poison bait suitable for aerial distribution have failed, most likely because goats are reluctant to eat food off the ground. A grain-based bait lured with molasses and chopped broadleaf leaves was eaten readily by feral goats held on a farm, but only six of 24 feral goats in a herd in the wild state ate these baits after aerial application (Parkes, 1993, *unpubl. Landcare Research contract report)*.

The process of allocating a tagged national fund (called a National Priority Pool or NPP budget) to control goats, ranking areas for control, strategic and operational planning, and operational and performance monitoring was begun by DoC in 1990 (Fig. 2).

During the 1980s, DoC and its predecessor (The New Zealand Forest Service) spent about $1.7 million per annum on feral goat control. During this decade an enthusiasm for farming goats for their fibre meant many feral animals were captured to act as base stock for improvement by breeding with angora goats (Anon, 1986). This industry proved not to be viable, and many new feral herds were created as goats were abandoned or escaped. Government responded to concern about this increasing problem and in 1990 allocated a budget of $3.8 million per annum tagged to control goats affecting conservation values (Caygill, 1990).

*Ranking areas for priority control operations*

The present budget allocated for goat control is sufficient to treat about one-third of the conservation estate with goats (Parkes, 1994, *unpubl. Landcare Research contract report)*. The question is which third? The answer is complex, but generally areas with the most important conservation values at risk to goats take priority. A system to rank goat-infested areas was developed by Llewellyn (1989, *unpubl. report to Bay of Plenty Conservancy)* and subsequently modified by Parkes (1991, *unpubl. FRI contract report)*. Basically, it scores on a scale of 1 to 6 the wildlife or botanical values present in each area with goats using systems developed by Ogle (1981) for wildlife, and Shaw (1988, *unpubl. FRI contract report)* for botanical values. The highest score is weighted by some measure of the risk posed by goats. Ideally, risk should be assessed in terms of the stability of the goat - resource interaction, with those presently stable being lightly weighted and those where the resource is being degraded heavily weighted.

In applying the system, DoC divided potential operational areas into those where eradication of goats was thought possible and those where sustained control would be needed. Areas with equal scores were further ranked if necessary by considering secondary hierarchies of land or management characteristics applied in a "sudden death" way to each strategic ranking (Le., eradication or sustained control). Areas of equal ranking for eradication were further sorted by considering the management goal in terms of the functional classification developed for islands (i.e., minimum impact, refuge, restoration, or open sanctuary - Atkinson, 1990), then the size of the area, probability of recolonisation, and finally land tenure. Areas of equal ranking for sustained control were further sorted, if necessary, by considering in order (until a separation was achieved) the lower of the wildlife or botanical score, then the presence or absence of other pests, their control, the inherent stability of the ecosystem, land tenure, probability of recolonisation, the nature of the impact of goats, and finally soil erosion.

The ranking process gave a national ranking that generally stood the test of common sense and was widely accepted by managers. This was despite lack of agreement about the nature of conservation values to be ranked (e.g., species versus ecosystems), knowledge about conservation values at many sites, the actual risks posed by goats, the manageability of each problem (could the resource be protected?), strategic considerations (eradication was preferred to sustained control), past control histories, and parochialism (each Conservancy wished to do something).

Conservancies identified and ranked about 500 areas with feral goats, covering about 20 000 $km^2$ of conservation estate. Control operations have now been carried out in 146 operational areas, covering about 10 000 $km^2$. Eradication has been the aim in 39 of these areas, and was apparently achieved in 14 areas up to June 1993 (Table 5).

The major areas funded for sustained control include Waipoua, parts of the Coromandel Peninsula, the Kaimai Range, the Hauhangaroa Range, the eastern Raukumara Range, all the North Island axial ranges from the Kaweka to the Rimutaka Conservation Parks, Mt Egmont National Park, Kahurangi National Park, Mt Richmond Conservation Park, parts of the Paparoa National

Park, and the eastern boundary of Mt Aspiring National Park.

Funds should become available from successful eradication campaigns and as one-off costs of new sustained control operations (e.g., fencing) are met. These should then be applied to the next highest ranked areas. These include further areas where eradication is thought possible (the plan lists a further 39 areas covering about 23 000 ha) and areas where sustained control would be required. This process allows for new operations to be started as one-off expenses are met, and so allows for re-consideration of the rankings of unfunded problems in light of new information.

The major area unlikely to be funded without additional funds is the huge forested area infested by goats that extends from the Wanganui River, north through the Matemateonga Range and inland Taranaki, to the forests west of Pirongia Conservation Park. In this area of about 300 000 ha, goats are controlled in only 39 000 ha (parts of Wanganui National Park, Moki/Makino, Taramoukou, Whitecliffs, Mokau River Scenic Reserves, Tawarau, and Puaroa).

*Has the control effort been sustained?*

One purpose of "contestable" budgets tagged within a national pest control plan is to ensure managers sustain the control efforts where necessary. The Department of Conservation is under budgetary constraints, but has numerous urgent problems its managers are urged or obliged to fix. The temptation is to use parts of major tagged pest control budgets to react to emergencies. The Department has been unable to resist some of this pressure, e.g., it has reacted to new liberations of sika deer by using money originally tagged for goat control (S. Kelton, *pers. comm.),* and pest budgets have been used to absorb some of the general reductions in Departmental votes.

In 1992-93, the department expended 6160 hunter-days (a day on which a hunter did any goat hunting) and 230 helicopter hunting hours controlling goats, killing 18300 and 5 200 goats, respectively. It also paid for the erection 10.2 km of fencing from the goat budget.

# Discussion

Wild goats are apparently typical of middle-sized ungulates with a general K-strategy life history. Domestication has enhanced some of the goat's r-strategist characters, increasing its propensity to become a pest. In particular, feral goats have high intrinsic rates of increase and are particularly social animals. Fortunately, in New Zealand they retain their ancestor's K-strategy character of reaching stable relationships with their resources (at least over the short to medium term), rather than the r-strategist's boom-bust lifestyle. This makes their impacts chronic but allows the system to be manipulated in favour of the resource by "chronic" or sustained harvesting of the population.

Left uncontrolled, feral goats have and will continue to modify indigenous ecosystems in ways most people find unacceptable. The patchy distribution of goats and the availability of successful and efficient control technologies means we have the ability to manage these impacts and can often eliminate them entirely. However, this management is made more difficult by three factors; the dual status of goats as feral pests and domestic animals (sometimes simultaneously), the biological characteristics of goats inherited from their ancestors via the process of domestication, and the difficulty that Government agencies have in sustaining control action in the face of competition for limited financial resources.

The first difficulty can be ameliorated by changing the law to distinguish more clearly between unwanted pests and wanted domestic stock, by changing the behaviour of goat farmers to ensure they do not hold goats adjacent to conservation estate and do effectively restrain their animals, and by improving the management of boundaries by upgrading fencing. We cannot change the fecundity of goats, so we have to manage their impacts by increasing mortality rates through control action.

The third difficulty is the crucial problem that must be solved. Unless managers can maintain some baseline budget for sustained goat control, or can eradicate feral goats, the long-term consequence of fluctuating budgets will be degraded ecosystems. The Department of Conservation has two broad choices to solve this problem for goats (and other pests):

- It can accept fluctuating budgets and apply them exclusively to attempts to eradicate pests. This would restrict action to islands and to patchily distributed pests on habitat islands on the mainland where the rules for eradication can be honestly applied. Some goat populations would be treated, but no populations of possums or other widespread pest species would be controlled on the mainland.
- It can attempt to organise the way it allocates resources so that baseline estate protection

functions are sustainable. The Department has a suitable process to do this, its Conservation Management Strategies. However, if these plans are to be anything other than a ranked wish-list of conservation actions, the actions need to be sorted into those that require ongoing budgets (baseline tasks such as sustained pest control) and those that can be achieved for a one-off, time-limited budget (such as pest eradication). A constant inviolate budget needs to be allocated for baseline tasks, and any fluctuation in resources managed within the second group of one-off tasks.

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