Eradication of feral goats from small islands

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Concern about the effects of feral goats on Aldabra atoll—a UNESCO World Heritage Site—led to a search for solutions. The search highlighted the inaccessibility of information on feral goat eradication campaigns. As a result the International Council for Bird Preservation and the FFPS, through its Oryx 100% Fund, commissioned a report to bring together and assess known techniques and potential strategies and to consider their implications for conservation practice. This article is a shortened version of that report.*

Destructive effects of feral goats and demands for their eradication are recurring themes in island conservation literature (Atkinson, 1964; Holdgate, 1967; Sykes, 1969; Wardle *et al.*, 1973; Bourne, 1975; Mueller-Dombois and Spatz, 1975; Pickard, 1976; Bullock, 1977; Coblentz, 1978; Newing *et al.*, 1984; Calvopina, 1985; Coblentz and van Vuren, 1987). Examples of positive ecological effects of feral goats are hard to find. Some argue that this is partly a reflection of research bias, but there is no disputing that 'feral Caprinae have the potential for ecological destruction' (Brooke, 1984) and that 'they are implicated in habitat destruction and the alteration of species composition of many sensitive insular ecosystems' (Howard and Marsh, 1984).

Feral goats eat seedlings, peel bark and even climb trees to reach canopy leaves. They often browse native species in preference to introduced ones (Baker and Reeser, 1972). Consequences include virtual destruction of a complete forest (Bullock and North, 1985), restriction of regeneration (Parkes, 1984a), and changes in species composition (Newing *et al.*, 1984; Coblentz and van Vuren, 1987). Feral goats have posed a major threat to over 26 per cent of island species in *The IUCN Plant Red Data Book* (Lucas and Synge, 1978). Every specimen of *Ranunculus caparum* yet discovered has had all flowers bitten off by feral goats (Lucas and Synge, 1978). The vine *Canavalia kauensis* was described only after the erection of a goat-proof exclosure, which allowed it to germinate and survive (Mueller-Dombois and Spatz, 1975).

Most feral goat impact on fauna is indirect, via habitat degradation. Other factors are often involved, making this impact hard to quantify. On Lord Howe Island feral goats, together with pigs, caused dramatic changes in habitat, which are believed to have brought the island's woodhen, *Gallirallus sylvestris,* close to extinction (Fullager and Disney, 1975). There are several reported cases of direct competition for food between feral goats and native island species. These include the Marquesas pigeon *Ducula galeata* (M. Fowler, in litt.), the New Zealand kokako *Callaeas cinerea* (Leathwick *et al.*, 1983), the Galapagos giant tortoise *Geochelone elephantus* (McFarland *et al.*, 1974), and the Aldabra giant land tortoise *Geochelone gigantea* (Coblentz and van Vuren, 1987).

Removal of feral goats does not guarantee a return to former habitat conditions. Some consequences of eradication may even be undesirable. Goat control on Round Island was accompanied by a sudden increase in *Tylophora taevigata*, an aggressive creeper, which may restrain re-establishment of native plants (Bullock and North,

*Daly and Goriup, 1987.

1985). Goat exclosures may show whether this kind of problem is likely.

It is vital to consider the socio-economic implications of eradication. On Masafuera eradication of feral goats would merely force islanders to increase their domestic stock, causing the same or worse damage (I. Castro, in litt.). It is also important to remember that feral herds may be of scientific value.

Having decided whether eradication is desirable for a given island, the next step is to assess whether it is feasible. Attempts to eradicate or control feral goat populations have been made on over 37 islands in the past 140 years. Eradication has been achieved on at least 20 of these and the New Zealand Forest Service (NZFS) was involved in over half of these successful campaigns.

Failure to appreciate the high potential reproductive capacity of feral goats has contributed to the ineffectiveness of many campaigns. Before control efforts on Pinta, the goat population increased from three to over 20,000 in just 12 years (Weber, 1971; Hamann, 1975). It is vital that the kill rate is greater than the rate of population growth. One way of measuring the success of a campaign is to plot the number of goats removed against a measure of effort, such as number of fieldworkers each day. This 'effort' is then increased until the daily cull shows a marked and continuously decreasing trend. Although circumstances will vary from island to island, it is advisable to maintain at least this level of effort throughout the campaign.

Once culling becomes effective in reducing population size, each kill becomes progressively more difficult. The final stage in the Raoul Island campaign illustrates this. The vegetation began to regenerate making survivors harder to locate and increasing food availability. The goats became extremely wary (Parkes, 1984b). In view of such problems J. P. Parkes (pers. comm.) recommended that the aim should be 'to kill as many (goats) as quickly and quietly as possible'. In order to do this campaigns commonly rely on hunters on foot, with or without dogs.

Casual *ad hoc* shooting—whether by local people (Galapagos), weather men (Raoul Island) or off-duty naval personnel (Kahoolawe)—is almost always ineffective. Hunters need to be highly skilled and committed to seeing the cull through to the last goat. Good team-work is important; von Berg (1981) describes an example of lack of co-ordination within a hunting party resulting in few animals being shot, the rest being scared away.

A good map and/or aerial photographs, combined with first-hand knowledge of the terrain are essential, particularly for identifying areas where surviving goats may take refuge. Knowledge of locations of traditional sleeping sites and home range boundaries is helpful. In several campaigns (including Raoul Island and Santa Catalina) goats did not disperse rapidly from traditional home ranges even under intense hunting pressure. Hunters can obviously exploit this phenomenon. Coblentz (1977) describes an area of Santa Catalina that was cleared of goats and not re-occupied for 20 years. However, he cautions that this phenomenon of slow dispersal is enhanced by topography and may not be as pronounced in flat open terrain (B. E. Coblentz, in litt.). More information is needed on the effects of control campaigns on goat dispersal.

New Zealand Forest Service hunters often work with indicating dogs at the start of a campaign. These silent dogs remain in close contact with hunters and lead them to the goats. Taking dogs into conservation areas involves risk to native wildlife, particularly if the dogs escape. It is essential that they are strictly controlled, especially in the vicinity of vulnerable species—such as ground-nesting birds—and that they are neutered.

Aside from small hunting parties on foot, two other methods have been used to kill large numbers of goats rapidly: shooting from helicopters and driving. The former technique reduced the goat population on San Clemente by around 91 per cent, but the survivors were left in difficult terrain (Howard and Marsh, 1984; Laycock, 1984). The campaign was interrupted several times by legal action, making it hard to assess how difficult it would have been to achieve eradication. Information from other campaigns suggests that it could have proved difficult. In Hawaii goats quickly learned to associate helicopters with danger and responded to the sound by hiding or remaining motionless (Anon., 1983). More infor-

Feral goats are capable of doing immense damage to vegetation in many parts of the world and their impact on fragile island ecosystems with threatened endemic species is particularly destructive (*Mark Boulton/ICCE*).

mation is needed, but in view of the above, helicopters may be best reserved for the final stages of a campaign or as an occasional supplement to other techniques.

Teams of people moving in well-co-ordinated lines have been used successfully in Hawaii to drive goats into the range of marksmen (Stone and Keith, 1984). Driving can also be used in conjunction with live-trapping, using temporary fences or natural barriers to funnel goats into corrals. One of the main disadvantages of driving techniques is the high level of disturbance—both to the goats and other species. The goats' increasing wariness and decreasing numbers makes driving less efficient over time.

There is little doubt that large numbers of goats could be killed rapidly by an intensive poisoning campaign. The main problem is the effects on native species. No poison kills goats exclusively and the only one worth considering is compound 1080, sodium fluoroacetate. Cyanide, arsenic, strychnine, phosphorus and anti-coagulants have all been used at some time against vertebrate pests, but all have serious drawbacks and no major advantages in comparison with compound 1080.

Originally developed in the 1930s as a rodenticide, compound 1080 is currently used worldwide in vertebrate pest control. It is commonly applied to artificial baits, which are either hand-laid or dropped from the air. In recent years trials have been carried out using natural vegetation baits, with some success against goats (Parkes, 1983). The method involves coating leaves on heavily goat-browsed trees with compound 1080 gel and bending them within reach of the goats. Towards the end of a campaign this technique becomes inefficient as falling goat numbers allow vegetation regeneration. There were no records of non-target poisoning in these trials.

Kills of non-target birds and mammals are quite common in campaigns involving artificial baits (Batcheler, 1978). The risk of non-target kills is

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particularly high if bait is distributed from the air because control over bait location is minimal. There is no clear evidence of long-term effects on non-target populations in any compound 1080 campaign, although this is not proof that no such effects exist. Impact will be particularly hard to measure on rare/vulnerable species (Spurr, 1979). An assessment of probable risk to non-target species—particularly rare/vulnerable ones—is important if a poisoning campaign is contemplated. Such assessments should include identification of species likely to eat baits or goat carcasses and/or be highly susceptible to compound 1080. It is clearly unacceptable to conduct laboratory trials on endangered species, and although the susceptibility of some rare species can be estimated from laboratory trials on similar but less endangered species, this is not possible for all species. (McIlroy, in press).

Non-target species may be affected by sub-lethal doses of compound 1080. In many species such effects include lethargy, which in reptiles may lead to severe disruption of normal behavioural thermoregulation (McIlroy *et al.*, 1985).

Studies from New Zealand have produced no evidence that compound 1080 persists for long periods in the environment (Batcheler, 1978). Such information is lacking for other parts of the world.

Chemosterilants have attracted the attention of vertebrate pest controllers in recent years, although at present there is no available chemosterilant suitable for goat eradication programmes. Future developments should be monitored.

In any campaign a point comes when most of the population has been killed. The few goats that survive are very wary and locating them is difficult. At this stage different techniques and tactics are required. Potentially appropriate techniques include hunting with bailing dogs, helicopter shooting platforms, use of 'judas' goats and kill snaring.

Bailing dogs bark as they chase goats. The NZFS employs such dogs to run goats down and hold them until hunters arrive. Alternatively, they can be trained to bark in a particular way when goats are exhausted, allowing hunters to move in. These techniques cannot be recommended in the vicinity of vulnerable species.

Helicopters can be very valuable for locating survivors in difficult terrain and were successfully used in this way towards the end of the Raoul Island campaign (J. P. Parkes, pers. comm.).

The 'judas' goat technique relies on the sociable behaviour of goats. A neutered goat is fitted with a radio-collar, released and tracked until it joins a herd. A helicopter can then be used to drive the goats towards hunters (Stone, 1984). The range over which signals can be received depends on the terrain, vegetation density and transmitter strength. The technique is intensive in skilled labour, equipment, time and money.

Snares were used with some success by NZFS on Raoul Island, but were only set on steep ledges and other places where death was likely to be rapid (J. P. Parkes, pers. comm.). Problems with snaring include the unacceptable levels of suffering inflicted upon snared individuals and the potential threat to non-target species.

The final stage of a campaign should be a follow-up survey to check that no female goats have survived. In the absence of other large mammals, aerial survey with an infra-red video camera could help locate survivors.

In any eradication campaign it is essential to maintain morale, commitment and funding to the end, and to appreciate from the start that eradication of the last few goats can be extremely expensive and difficult. On Raoul Island, eradication of the last five goats cost US$6000 a goat (J. P. Parkes, pers. comm.). As experience from so many campaigns illustrates, 'if you do not eradicate the last reproductive unit, you are wasting your time and money' (P. Munton, in litt.).

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