An Economic Evaluation of Feral Goat Control Methods in the Rangelands of Western Australia

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Introduction
The feral goat (Capra hircus) is a cause for major concern throughout Australia, particularly in WA. It is extremely important to implement measures designed to counter its effects since a failure to do so will have dire consequences for pastoralism in the state. This paper discusses many of the issues surrounding goats, touching briefly on certain harmful biological characteristics, the types of damage and costs they cause, and also commercial industry. The crux of the paper is to present a framework for analysis of control policies available to Agriculture WA based on the Schaefer model, and to comment on their efficiency and effectiveness. While present control efforts can be seen to be effective using this framework, there may be certain difficulties to be overcome in reality is goat numbers are to be brought nearer a socially optimal level.

Background
Abundance and Distribution
Goats are widely distributed across WA, which has the largest population of any state. They were first declared vermin in 1928 under the Vermin Act (1918), and remain so to this day under the Agriculture and Related Resources Protection Act (1976). The animal is considered a pest on the rangeland, which is predominantly of pastoral use.

Opportunistic counts of feral goats have been undertaken during aerial surveys of kangaroos in the WA rangelands conducted by the Australian Nature Conservation Agency (ANCA) in 1987, 1990, and 1993. The recorded figures have not been corrected for visibility bias (Southwell and Everleigh, 1992, p. 19), so the results of the ANCA aerial surveys, reported in Table 1, merely provide minimum estimates of population size.

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<tr>
<th>Year</th>
<th>Estimated Population</th>
<th>Standard Error</th>
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<tr>
<td>1987</td>
<td>336,000</td>
<td>± 44,000</td>
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<tr>
<td>1990</td>
<td>596,500</td>
<td>± 41,200</td>
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(Southwell and Pickles, 1993).

These estimates constitute an increase of around 18% per annum, given that 187,000 goats were known to be commercially harvested each year in between surveys. The population in 1993 was reported as 447,500, indicating a drop of some 40% (Pickles, 1994), which can be attributed to the Feral Goat Eradication Program (FGEP).

In WA, goats have been observed to occur in a broad band stretching north-west to south-east across the state from the western coastline near North West Cape,
but stopping short of the Nullarbor Plain (Southwell and Everleigh, 1992, p. 19). They are present on over 270 pastoral stations in the southern pastoral region, and on average contribute 20% of total grazing pressure, with sheep contributing 46% and kangaroos 34%. However, on some properties in the Upper Gascoyne, they contribute more than 50% of total grazing pressure, while on properties elsewhere their numbers are very low (APB, 1993, p. 10). As the population size increases, and competition for scarce food and water supplies mounts, goats are moving into other areas where they have not previously been sighted.

**Rangeland Diversity**

The arid and semi-arid rangelands which are of primary concern here, make up a very substantial part of the Australian landscape, comprising of over 70% of the continental land area. Feral goats are largely confined to those rangeland areas grazed by sheep, where they compete directly with commercial stock for food and water. Included in the occupied areas is a great diversity of landforms and vegetation communities, ranging from the arid shrublands in WA which receive an average annual rainfall of 200 mm or less, to arid woodlands in the western division of NSW which receive up to 400 mm, and into the tropical grasslands of Queensland (Hacker, 1992, p. 3).

**Biology**

The goat has a range of characteristics which make it superbly adapted to life on the rangelands, and extremely destructive. It is a very resilient animal, which makes it a rather difficult one to deal with. Some of its key characteristics are a very high reproductive rate, high level of drought tolerance, extremely broad grazing habits, cloven hoofed feet and a high mobility with large home ranges.

**Economic Costs**

It is possible to group economic costs into three general categories. Firstly, there are management costs comprising of outlays from state and national government bodies associated with the management of feral goats, which have been considerable for a number of years. Secondly, there are Costs to Production which can be estimated at around $2.5 million in 1993 using a Marginal Damage Cost of $5.60 per goat per annum from South Australia (Henzell, 1991, p. 305). Finally, there are Costs Related to the Threat of Exotic Disease, since a large feral goat population greatly increases the potential costs associated with an exotic livestock disease.
Environmental Costs
Perhaps the most severe losses suffered as a result of the presence of large numbers of feral goats are borne by the environment. Once again, we can divide these costs into three basic types. Firstly, is soil degradation caused by the biological characteristics previously mentioned. Secondly, goats can have a profound impact on the composition of vegetation on the rangelands. And finally, effects on native animals can be quite severe given that they compete directly for food and water. All environmental damage of this type cannot be contributed to goats, as there are many other vertebrate pests which make a significant contribution.

Commercial Use
Despite the destructive capabilities of goats, they can be seen to generate a considerable amount of export revenue for Australia every year, a great deal of which is received through WA. The meat industry accounts for much of the earnings derived from the national goat population. In fact, Australia is now the largest exporter of chilled and frozen goat meat in the world, with the main competitor being New Zealand (Ramsay, 1994). There are also a range of other products which generate income, including live goats, skins, leather, and fibre. Because the income from domestic goats is included in trade statistics, it is difficult to accurately value the income from feral goats. However, the total export value of products was placed at $27.5 million in 1991 (Ramsay, 1994), with feral goats contributing a substantial amount. Just how substantial is difficult to say.

Eradication as a Public Good
Optimal Control Policies in a Static Model
Feral goats are an example of a renewable common property resource in that the population exhibits the characteristics of rivalry in consumption and unrestricted access. The stock level is not fixed, and if unimpeded its size will increase through the process of regeneration. Beginning at a low level of population, goat numbers expand due to breeding, but at a steadily decreasing rate as they begin to compete for food and water supplies. Growth of the stock will continue until the natural equilibrium is reached, where the population level corresponds to the carrying capacity of the ecosystem.
If one were to somehow cause a one-off reduction to the stock, making it fall below the natural equilibrium, there is a tendency for it to return to its original level through regeneration. Therefore, it is possible to perpetually harvest the increase in the stock. The relationship can be represented in a growth curve, shown in Figure 1. This framework was originally developed by Schaefer (1957) for use in the management of fisheries, but is applicable here. It is static, and represents an average relationship in the sense that it abstracts from influences such as climatic conditions and the age structure of the population (Tietenberg, 1992, p. 305).

At $S_{\text{max}}$, the stock level is consistent with the natural equilibrium situation. This point is stable since a population level above or below it sets natural forces in motion which act so as to return the population to its original level. For example, a larger population than $S_{\text{max}}$ means that the population level exceeds the carrying capacity of the land, leading to excessive competition for food and water. In contrast, the point $S_{\text{min}}$ is unstable. This can be termed the critical minimum population level, referring to that level of population below which extinction will result. It is unstable in the sense that there are no natural forces causing the stock level to converge on that point.

A sustainable yield is one where the rate of harvest is equal to the growth rate of the population. If the harvest is equal to growth, the sustainable yield for any population size between $S_{\text{min}}$ and $S_{\text{max}}$ can be determined by drawing a vertical line from the stock level up to the point where it intersects the curve, and then drawing a horizontal line across to the vertical axis (Tietenberg, 1992, p. 307). Therefore, in Figure 1 the sustainable yield for a population size of $S'$ is $G(S')$. The point $S^*$ corresponds to the Maximum Sustainable Yield (MSY), which occurs when the growth rate of the
resource reaches a maximum, \( G(S^*) \). This is the most we can harvest from a resource without reducing the long-term stock.

Let us now broaden our analysis with a discussion of Total Benefits (TB) and Total Costs (TC). Consider a situation where hunting takes place, requiring some level of effort \( E \). We shall assume that the price for goat carcasses/products \( p \) is constant, and that the only cost associated with a person's hunting effort is the opportunity cost, or the wage rate \( w \). This may not be altogether realistic since we are ignoring capital costs, such as hunting equipment, in order to keep the analysis relatively simple. Also, assume that every hunter is equally proficient at his/her task.

The output of goat products \( q \) can be expressed as a function, \( f \), of the amount of effort required to obtain it

\[
q = f(E) = f(\sum E_i)
\]

where,

\( E_i \) = the effort expended by the \( i \)th individual.

The expression for total benefit is then easily obtained by multiplying the function \( q \) by \( p \), and summing across all individuals. This is the gross benefit hunters will receive as a result of their hunting efforts, which may be termed private total benefits, \( TB_p \).

\[
TB_p = p.f(E)
\]

Total costs are given by the opportunity cost of hunting time, or the wage rate, \( w \), multiplied by the actual amount of hunting effort, \( E \). Recall that the only cost associated with hunting is assumed to be \( w \).

\[
TC = w.E
\]

Both the \( TB_p \) and TC curves are shown in Figure 2. Because \( p \) is constant, the shape of the \( TB_p \) curve is the same as the growth curve of Figure 1. This is often referred to as the Biological Yield Curve. The TC is simply a straight line from point \( E_{\text{min}} \) whose slope is given by \(-w\), assuming that the marginal cost of hunting is equal to the average cost. Let us suppose that there are only a limited number of hunters with access to the resource. Presumably, they will be profit maximisers and act so as to maximise returns from the resource usage, whilst being constrained by TC. This being the case, we can state the hunters' maximisation problem as:

\[
\max_E \Pi = p.f(E) - w.E
\]

where;

\( \Pi = \text{profits} \).
In terms of the diagram, they will choose to expend an amount of hunting effort $E_c$, for at this level the vertical distance between $TB$ and $TC$, or Net Benefit, is maximised. At $E_c$, the Marginal Cost (MC) and Marginal Benefit (MB) are equal, and be termed the static efficient sustainable yield, or maximum economic yield (MEY), since it maximises the (identical) net benefit in every period. Only at this point can rational goat management, or control practices be considered optimal in the static model.

If the number of hunters with access to goats is no longer fixed, agents will enter the market due to the lure of profit. As a result the resource may be over-utilised, and net benefits dissipated. Hunters will then have little incentive to conserve the resource since this would mean a larger number of goats available for the next. Therefore, rather than equate MC with MB, hunters will equate TC with TB under competition, and expend a hunting effort of $E_c$. This is not a conscious decision, but is simply the result of self-interest underlying the system. Clearly, $E_c$ is above the optimal level, $E_o$.

**Optimal Control Policies in a Dynamic Model**

Goats are an exhaustible resource, and so harvests in the present time period can greatly effect the quantity available for future generations. Therefore, it is appropriate to look at the present value of benefits associated with the use of goats in the present and future time periods. Basically, in the static efficiency solution the discount rate is equal to zero, and there is a strong incentive for the users of the resource to conserve by operating at $E_c$. However, if it is positive the dynamic efficient hunting effort will lie to the left of point $E_c$, beyond MEY in terms of Figure 2. The furthest point it could reach is $E_c$, where $r$ is infinite.
Socially Optimal Level of Control

The total benefit to society from goat control, TB_s, will take on some value greater than TB_p, for when goat numbers are reduced, so too are the damages they inflict. The private market does not appropriate the damage reduction whereas society does. So, there are positive externalities, or external economies associated with goat destruction, which are included in society's total benefit.

The size of the externality, X, will depend on the number of goats removed, and therefore on the amount of hunting effort exerted. The size of X will be equal to the product of the Marginal Damage Cost and the level of hunting effort, E.

\[ X = cE \]  
where; \[ c = \text{MDC} = \text{ADC} \]

The TB_s can now be expressed as the sum of TB_p and X.

\[ \text{TB}_s = \text{TB}_p + X \]  
\[ \text{TB}_s = p.f(E) + cE \]  

It is appropriate to label eradication a public good in that it can be seen to exhibit consumption indivisibilities and free access. Thus, there exists a free rider problem with feral goat hunting as society is able to reap the rewards of hunting efforts without contributing to them. Thus, it is very difficult to obtain a level of hunting effort that is consistent with a socially optimal level.

In terms of a diagram, the TB_s curve will lie everywhere above the TB_p curve, as shown in Figure 3. As it has been drawn here the socially optimal level of hunting effort, E_s, is greater than E_p, indicating that there is an under-supply of eradication. However, it is not necessarily the case that the TB_s curve looks like the one in Figure 4. Its shape may be very different and cause the socially optimal level of eradication to occur at different quantities of hunting effort.

Policy Options and Their Effectiveness

There are essentially three policy options from which to choose. Firstly, there is always the option of doing absolutely nothing, which is extremely dangerous in this case. Secondly, a commercialisation policy may be put in place, aiming to fully utilise the goat stock as a resource. Thirdly, an eradication program may be pursue, as is the case at the moment. Strictly speaking, the goal of the program is reduce and sustain the population of goats in the state to a low level, so it is more strategic management than eradication. This is the preferred option from the Agriculture WA's point of view.

Commercialisation policies have been adopted in the past in order to reduce the goat population, but have met with only limited success. While positive results have been
Figure 3: The Total Benefit to Society from Eradication

\[
TC = wE \\
TB = TB + X \\
MSY
\]

Goat Stock   Hunting Effort

In WA, a commercialisation policy was first introduced in 1973. One of the incentives used involved the payment of a bounty on goats' ears to encourage people mustering goats to destroy unmarketable animals rather than releasing them, which ceased in 1985 (Parkes et al., 1995, p. 36). However, despite over 2.25 million goats being killed between 1973 and 1990, the total population actually increased (Pickles, 1994, p. 2), as the private sector failed to take into account the externality created by the destruction of goats.

In response to the concerns of pastoralists, the APB commenced the FGEP in 1991, originally with the aim of eliminating feral goats from the arid shrubland pastoral areas by the year 2000. In order to control the program's direction and the development of policy, a steering committee was established, comprised of representatives of all parties affected. The program has been very effective in reducing feral goat numbers. Between the time of its implementation to June 1995, over 1.15 million have been removed from the rangelands. It has been estimated that this has caused a drop in numbers by around 40 per cent. Table 2 indicates the total destruction figures.

Table 2: Feral Goat Destruction Figures, 1991/92 - 1994/95

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<tbody>
<tr>
<td>Sold</td>
<td>310,666</td>
<td>243,189</td>
<td>151,057</td>
<td>90,195</td>
</tr>
<tr>
<td>Destroyed</td>
<td>182,783</td>
<td>169,522</td>
<td>170,575</td>
<td>128,060</td>
</tr>
<tr>
<td>TOTAL</td>
<td>493,449</td>
<td>412,711</td>
<td>312,632</td>
<td>218,255</td>
</tr>
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(Pickles, 1995).
By including goats in the overall stocking rates of individual properties, the externality may be internalised. The land occupied by feral goats is held under pastoral lease, and lessees are obliged by the Land Act (1933) to follow the terms of use set out by the Pastoral Board (Parkes et al., 1995, p. 37). Within the lease, stocking rates of sheep and other domestic livestock is limited, but unmanaged grazers are not included. This leads to widespread overgrazing, since stocking rates exceed the carrying capacity of the land. The term total grazing biomass refers to both managed and unmanaged grazers, and this is the concept which must be used in order to internalise the externality.

Figure 4 shows the effect that this would have on the private and social total benefit curves. The private sector's total benefit curve, $TBP$, will shift upwards from $TBP'$ to $TBP''$, and become closer to Society's total benefit curve, $TBS$. This must be the case since the costs of violating the terms of pastoral leases are avoided by controlling goat numbers, and are therefore included in total benefits

\[ TBP = p.f(E) + a \]

where; \[ a = \text{avoided penalty} \]

As a result, the privately optimal level of hunting effort, $Ep$, will increase from $Ep'$ to $Ep''$ as we have constructed the curves in the diagram, which is closer to the socially optimal level, $Es$.

**Problems**

The major problem with this approach is how to enforce recommendations when there are a very large number of properties spread over a huge area. Furthermore, it may be difficult to determine if a landholder is mismanaging when it is unclear just what population of goats is considered acceptable by the steering committee. True
eradication has very rarely been observed and would be extremely costly to achieve, so it is logical to think more in term of a strategic management approach. Unfortunately, maintaining any population of goats will mean on-going damages and costs. So, how much is too much?

There is also a growing concern about the lack of monitoring activity, and the subsequent lack of knowledge about the effectiveness of the program. Steps are presently being taken to increase the level of monitoring, but it is important that this be through increased funding, rather than simply a reallocation of resources within the project. If the latter occurs, than this will undoubtedly mean a reduced hunting effort. While this would aid direction within the project, the rangeland could be the loser if pressure on the goat population is not maintained.

A large hurdle for economists dealing with pests like feral goats is the inability to quantify environmental goods. In this sense, Benefit Cost Analysis (BCA) is severely limited in its ability to indicate which policy approach yields the highest returns to investment because some of the more significant benefits and costs can not be valued. The on-going debate in the literature over the validity of results obtained using Contingent Valuation makes this a highly questionable approach to use, which casts significant doubt over the practicality of BCAs.

Conclusion

The framework developed in this paper may be applicable to similar situations elsewhere. A range of issues have been touched on here, including the troublesome aspects of goat biology, the costs and benefits derived from them, and the policy options available to counter the problem. The present policy approach can be seen to be effective in terms of economic theory, but in practise this may be somewhat more difficult. It is essential that pressure is maintained on the goat population in pastoral areas to prevent severe damage to the rangeland environment, and to pastoral output. Benefit Cost Analysis is of limited assistance when dealing with issues of this nature since many of the benefits and costs are not quantifiable. So, the economics of goat control is by no means simple, and it is difficult to offer suggestions as to how resources within the Feral Goat Eradication Program can be put to optimum use.
Bibliography


