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ANALYSIS OF VERTEBRATE PEST RESEARCH

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ABSTRACT: Research on vertebrate pest control is mostly empirical, focusing on control of species X in location Y using method Z. Such an approach is needed. The science of vertebrate pest research is developing some generalizations across species, locations, and methods. This paper further explores such generalizations by discussing six questions asked by Hone (1994), the answers to which are relevant to vertebrate pest research world-wide. Several case studies are examined, with emphasis on control of damge by small mammals and predation control. Suggestions are made for future research.

KEY WORDS: analysis, economic damage, efficacy, evaluation, vertebrate pest control

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INTRODUCTION

The emphasis in this paper is on ideas common to many areas of vertebrate pest research on damage and control. In particular, the author asks six questions on the analysis of vertebrate pest control as highlighted in Hone (1994). The questions are linked by being explicit or implicit in any economic evaluation of vertebrate pest control. Hence the questions are generic and underlie much of vertebrate pest research. The aim is to summarize current knowledge and identify future areas of vertebrate pest research including suggesting how different analyses can be better integrated. The research is relevant to control by lethal and non-lethal methods. Non-lethal control may include immunocontraception as described by Tyndale-Biscoe (1994).

1. IS THERE A RELATIONSHIP BETWEEN THE ABUNDANCE OF PESTS AND PEST DAMAGE?

Vertebrate pest control has a fundamental assumption that there is a positive relationship between the number of pests and the damage they cause. The existence and form of the relationship has been explored theoretically by several authors, such as curved (Izac and O'Brien 1991) and linear and curved (Braysher 1993; Hone 1994; Bomford et al. 1995). The study of Hone (1994) collated empirical data from 21 studies and reported only 13 (62%) as showing a significant linear relationship. Further collation and analysis of data shows that 21 (54%) of 39 studies show a significant linear relationship. The most likely reasons for non-significant results are that variables may be measured with low precision and so a type II error has occurred, the underlying relationship is a curve not a straight line, what has been measured as damage is not linearly related to actual damage, or that other sources of variation were not included in the analysis so the strength of any underlying relationship between damage and pests has been underestimated, and hence a type II error has again occurred. Hone (1994) developed a mathematical model of the relationship.

Headley (1972), in describing pests in general, assumed a positive but curved relationship (concave up). A concave down curve was hypothesized for feral pigs (*Sus scrofa*) and damage in Australia by Izac and O'Brien (1991). Five (13%) of 39 studies have reported a curved relationship between pest abundance and pest damage, so a total of 26 (21 + 5) studies (67%) have reported a significant positive relationship. Feare (1974) calculated that increasing numbers of rooks (*Corvus frugilegus*) in northeastern Scotland resulted in increases in damage to crops of oats and barley. The damage increased at a decreasing rate. A similar trend in the relationship was reported for lamb predation by feral pigs in southern Australia (Choquenot and Lukins 1995).

There appears to be only one study (Croft 1990) which has tested the relationship of rabbits (*Oryctolagus cuniculus*) and it was reported that there were significant effects (plant height, sheep liveweight, and fat depth) and non-significant effects (plant species composition and greasy fleece weight). There was no significant linear effect of rabbits on the fiber diameter of wool, but there was a significant curvilinear effect on fiber diameter. Rabbits were experimentally held at high densities in that experiment. For studies of predation of livestock, Wagner (1972) considered there was a significant relationship between coyote (*Canis latrans*) abundance and predation in the western USA, but did not test it.

2. IS THERE A RESPONSE OF PEST DAMAGE TO CHANGE IN PEST ABUNDANCE AFTER PEST CONTROL?

The logical follow-up to question 1 is to ask the above question. In other words, if pests are reduced in numbers by pest control, is damage reduced? This question is ripe for experimental picking. There are surprisingly few tests of the question (Table 1) and what tests have been made give mixed results.

Brown (1993) reported some significant effect of rabbit control on pasture biomass but also many non-significant effects in an area in southern Australia. In the same experiment Williams and Moore (1995) reported significant and non-significant reductions in rabbit abundance depending on control treatments. The results, in Table 1, of Foran et al. (1985) and Tobin et al. (1993) are sobering reminders of the distinction between the response to pest control (rabbits and rats, respectively) of pest abundance (in both studies significant) and of pest damage (non-significant in both studies). Both results could be explained by a concave down relationship

Table 1. Studies where the responses to vertebrate pest control, of both pest abundance and pest damage, have been estimated as statistically significant ($P<0.05$) or not significant (NS, $P>0.05$).

Pest	Pest Abundance	Pest Damage	Reference
Rabbit (*Oryctolagus cuniculus*)	Significant	NS	Foran et al. (1985)
Rabbit	Significant, NS	Significant, NS	Williams and Moore (1995), Brown (1993)
Feral pig (*Sus scrofa*)	Significant, NS	Significant	Hone (1987)
House mouse (*Mus domesticus*)	Significant, NS	Significant	Twigg et al. (1991) Singleton et al. (1991)
House mouse	Significant	Significant	Mutze (1993)
Rat (*Rattus* spp.)	Significant	NS	Tobin et al. (1993)

between pest abundance and damage. That shows that substantial changes in pest abundance could occur with little or no change in pest damage if pre-control abundance was high.

Kinnear et al. (1988) reported a study of foxes (*Vulpes vulpes*) and predation of rock wallabies (*Petrogale lateralis*) in southwestern Australia. The results have been widely cited, for example Bomford et al. (1995), Burbidge and Wallace (1995), Morris et al. (1995), and Pech et al. (1995), and used to justify fox control and hence predation control. The study, however, did no statistical analysis of the effects of fox control. Usher (1989) commenting on the same data, stated, "This experiment, with replication of controlled and uncontrolled alien predator populations on five rocky hill outcrops, should provide valuable information when all of the monitoring data are analyzed." Hone (1994) independently noted the lack of analysis and has reported the results of two analyses, which found a significant or non-significant effect of fox control depending on the response variable analyzed (rate of increase and abundance, respectively). Obviously, more data were needed in the original study, as was an analysis. Saunders et al. (1995) provide more data and clearer trends, but still no analysis. Caughley and Gunn (1996) were critical of the experimental procedure.

An effect of fox poisoning on abundance of chuditch (*Dasyurus geoffroii*) in southwestern Australia was reported by Morris et al. (1995). Indices of chuditch abundance were reported over several years in two areas; one with 1080 poisoning of foxes and one with no 1080 poisoning. There was apparently no statistical analysis of the data (D. Choquenot, pers. comm.), yet the authors concluded that fox control was beneficial for chuditch. The observed rate of increase of each chuditch population can be estimated by the regression of the natural logarithm of indices over time (Caughley and Gunn 1996), using data for October or November in 1991-1993 inclusive in Table 1 of Morris et al. (1995). Chuditch are seasonal breeders (Strahan 1983), so data only from the one time of year were used to estimate rate of increase. In the experimental control area (no 1080 poisoning) the observed rate of increase was 0.92 per year, but the regression was not statistically significant (df = 1, $P>0.05$). In the treatment area (1080 poisoning occurred) the observed rate of increase was 0.76 per year, but the regression was also not statistically significant (df = 1, $P>0.05$). Both regressions were approaching significance but used few data, so more data are required to reach a more definite conclusion (more statistical power), about the effect of predator (fox) control. The point to emphasize here is whether effects of fox predation control have been clearly demonstrated. There may well be a big effect but without a statistical analysis, and a more powerful analysis, it is difficult to separate the message from the noise.

Harris and Saunders (1993) were critical of the poor evaluation of canid control operations. They described the results of many studies from around the world only some of which had measured a response in predation and only a subset of those had tested for a significant effect.

3. WHAT IS THE SPATIAL FREQUENCY DISTRIBUTION OF PEST DAMAGE?

The question focuses particularly on whether all areas or sites have similar damage or not. Hone (1994, 1995) reported several studies that showed a highly skewed (mostly negative exponential) frequency distribution of damage. That is, many sites had no damage, some had little damage and very few had a large level of damage. So what? Obviously, if control is applied uniformily it will be wasted on the many sites that have no damage. If control is targeted to those few sites with high damage, then it should be more economic.

Study on rabbits in New Zealand has ranked areas "rabbit proneness" (Williams 1977, Kerr 1991). "Rabbit proneness" is the same concept as the frequency distribution of damage but a coarser measure of it, particularly if rabbit abundance is used rather than specific measures of rabbit damage. Crawley and Weiner (1991) reported that parameters of the frequency distribution of sizes of wheat plants varied in response to rabbit grazing in a study in Britain, so there is potential for spatial variation in such effects.

Six studies reported in Hone (1994) assumed the spatial frequency distribution of predation of livestock in the western USA followed a Poisson or Poisson-type distribution and hence predation occurred at random. However, nobody actually tested the goodness of fit. Hone (1994) did for the one data set that presented the raw data, and showed a significant difference from a Poisson distribution. Data on the spatial frequency distribution of damage by other predators is limited. Rowley (1970) presents data on estimates of lamb predation by foxes in Australia. Collation of the data on the number of healthy lambs killed by predators as a percentage of all lambs, shows a skewed frequency distribution of predation though the conclusion is limited by the small sample size. The estimated losses and their frequencies were 0 to 5% (n=6), 5.1 to 10% (n=2), 10.1 to 15% (n=1), and 15.1 to 20% (n=1).

The spatial variation in damage to pistchio orchards in a part of California varied with species of bird (Crabb et al. 1994). Damage by scrub jays (*Aphelocoma coerulescens*) was randomly distributed, but damage by American crows (*Corvus brachyrhynchos*) was aggregated. Both distributions were statistically tested by examination of the variance to mean ratios.

4. WHAT IS THE RESPONSE TO PEST CONTROL OF THE SPATIAL FREQUENCY DISTRIBUTION OF PEST DAMAGE?

The question is a logical consequence of question 3. The question appears not to have been answered for vertebrate pests and their damage. The practical interest in the question and the answer comes from attempts to determine the economics of pest control; is control economic in all areas or only in some areas. Several responses are possible as shown in Hone (1994). The pre-control distribution could be shifted to the left, or altered to become a bimodal distribution depending on where control occurred and its effects. The model of Crawley (1983) of herbivore damage could also be used to study the dynamics of any change in frequency distributions. Anderson (1982) and Anderson and May (1982) applied a model of parasites and reported that the most efficient control was achieved by applying control to hosts (areas) with highest numbers of parasites (pests).

5. WHAT IS THE RELATIONSHIP BETWEEN THE LEVEL OF PEST CONTROL EFFORT AND THE NUMBER OF PESTS KILLED?

If research on control changes from asking "what is the effect of control" to "what is the effect of different levels of control," then question 5 is appropriate. It is expected that the relationship will be positive (more effort, more killed). Hone (1994) listed 14 models that have been or could be used to study the relationship. Six models made some explicit assumption (linear or curved) about the relationship. The other eight models in Hone (1994) assumed the number of pests killed was independent of effort. The models have not been thoroughly compared. The practical interest in the relationship is that the level of effort is presumably a major determinant of cost and potential benefit of control. Linear and curved forms of the relationship have been reported for shooting of feral pigs (Saunders and Bryant 1988; Hone 1990, 1994) and feral water buffalo (*Bubalus bubalis*) (Skeat 1990).

Headley (1972) described an inverse relationship between cost (time) per kill and pre-control pest abundance, and Tisdell (1982) critically reviewed the idea and illustrated what may influence it. Such inverse relationships have been reported for several vertebrate pests, such as feral water buffalo (Ridpath and Waithman 1988), feral donkeys (*Equus asinus*) (Choquenot 1988), feral goats (*Capra hircus*) (Parkes 1993), and feral pigs (Hone 1994; Bomford et al. 1995; Choquenot and Lukins 1995).

The practical significance of the results is clear—as pest abundance is reduced, the cost per kill increases exponentially and may be a reason why pest eradication is sometimes not achieved (Bomford et al. 1995).

6. WHAT LEVEL OF COSTS OF PEST CONTROL MAXIMIZES THE ECONOMIC BENEFITS OF CONTROL?

The question, or its many cousins and other relations, would appear to be the most fundamental of questions in vertebrate pest research. Yet, it hardly appears to have been answered. Underlying question 6, and its answer, are each of the previous questions. The nature of the response of damage to control will be determined by the underlying relationship (questions 1 and 2) and its variation in space (questions 3 and 4) and the link between control effort, costs, and kills (question 5).

Hone (1994) reviewed many of the general principles and concluded there is a need for further research on the topic. The study of the response of pronghorn to control of coyotes (Smith et al. 1986) is a notable exception to the deficiency. Field data on trapping and shooting were combined with a computer model of pronghorn (*Antilocapra americana*) dynamics and control. As several control strategies were simulated, one could identify the strategy (level of costs) which maximized benefits and then compare the net benefits and the benefit:cost ratios, though the latter were not calculated in the original paper but were described by Hone (1994). Choquenot and Lukins (1995) used a similar mix of field data and modeling to estimate the benefit:cost ratios for control of lamb predation by feral pigs. Bomford et al. (1995) showed that incorporating discount rates into an economic analysis of eradication may delay the time until the benefits of control exceed the costs of control. The higher the discount rate, the longer the delay.

CONCLUSIONS

The researchers tend to study aspects of control of species X, in location Y, using method Z. They need to do that. They also need to generalize a bit more to identify common ideas and results. The continued development of a rigorous science of vertebrate pest research requires successful attempts at generalization. The analysis of vertebrate pest research can be improved by doing statistical analyses and interpreting their results rather than solely interpreting the original data, using field data to test the assumptions and predictions of models, and greater use of economic analyses by involvement of economists, similar to how biometricians are (or should be) involved.

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