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AN APPROACH TO THE DESIGN OF TARGET-SPECIFIC VERTEBRATE PEST CONTROL SYSTEMS

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ABSTRACT: Vertebrate pest control has the dual objectives of maximizing efficacy and minimizing nontarget hazard. The task in design is to make these objectives complementary, rather than mutually exclusive. Historically, vertebrate pest control has emphasized target control as a single objective, with nontarget impact a subsequent, secondary consideration. This sequence necessarily constrains the capacity of the design process to minimize nontarget impact.

I describe a framework for the design of vertebrate pest control which is based on comparative evaluation of the socioecology of target and potential nontarget species. Using this approach, control systems are designed which focus on and exploit identified differences between target and nontarget species. This approach aids the design of control systems which optimize efficacy and nontarget impact. Further, it facilitates identification of needed research and development, specifies potential problems of nontarget impact, and enables system redesign and refinement prior to implementation. The approach is illustrated with the example of poisoning programmes for feral pig control in Australia.

INTRODUCTION

Vertebrate species attain pest status when they have detrimental economic or aesthetic impact on human activities. We seek to economically reduce that impact by exclusion and control. Control can be achieved in a number of ways, including direct measures such as poisoning, trapping, shooting, and reproductive inhibition, and indirect means such as habitat manipulation.

A concurrent objective of contemporary vertebrate pest control is that it be selective, exerting a specific influence on the pest, or target species, while simultaneously having acceptable impact on other species. In this context, acceptable nontarget impact is a complex and variable quantity, which changes with the species, time, place, and value system of the observer.

Historically, the design of vertebrate pest control has been ad hoc, emphasizing target control as a singular objective. Except in the case of domestic species, nontarget impact has been perceived as a subsequent and secondary consideration. Although the desirability and importance of minimizing nontarget impact are now widely recognized, means of addressing the problem are often not a part of the initial design process. Typically, a system of target control is developed and implemented, then the system's nontarget impact is assessed and means of reducing it are considered as subsequent modifications. This post hoc approach places clear constraints on the extent to which considerations of nontarget impact can significantly influence design.

An additional impediment to the development of control systems which meet target and nontarget objectives is the absence of any framework upon which to design and evaluate vertebrate pest control systems. Although researchers are increasingly cognizant of nontarget considerations, there is currently no systematic or comprehensive basis for approaching these problems.

This paper describes an approach to the design of vertebrate pest control which is based on comparative evaluation of the biology and behaviour of target and potential nontarget species. Its aim is to provide a systematic framework for the design of vertebrate pest control systems which optimize target impact and primary nontarget hazard. Although formulated specifically for, and illustrated with, the design of feral pig control using poisons, it can be generalized to other pest species and control techniques. The proposed approach comprises five steps, which are summarized in Figure 1. The first of these is a systematic comparison of the target and potential nontarget species using a set of socioecological parameters.

COMPARATIVE SOCIOECOLOGICAL EVALUATION OF TARGET AND POTENTIAL NONTARGET SPECIES

It is axiomatic that sympatric vertebrate species differ in some aspects of their biology and behaviour and are similar in many others. The task here is to compare target and potential nontarget species systematically to identify areas where "usable" differences exist. Niche theory (Hutchinson 1958, Levins 1968) provides a useful heuristic and operational tool in this context. If we envisage a species' niche as a multidimensional representation of its resource utilization (Hutchinson 1958) our primary interest lies in parameters where niche overlap is minimal or nil. Levin's (1968) observation that niche refers not to the number of biologically relevant factors in the environment, but to the parameters which serve to separate species, is relevant here.

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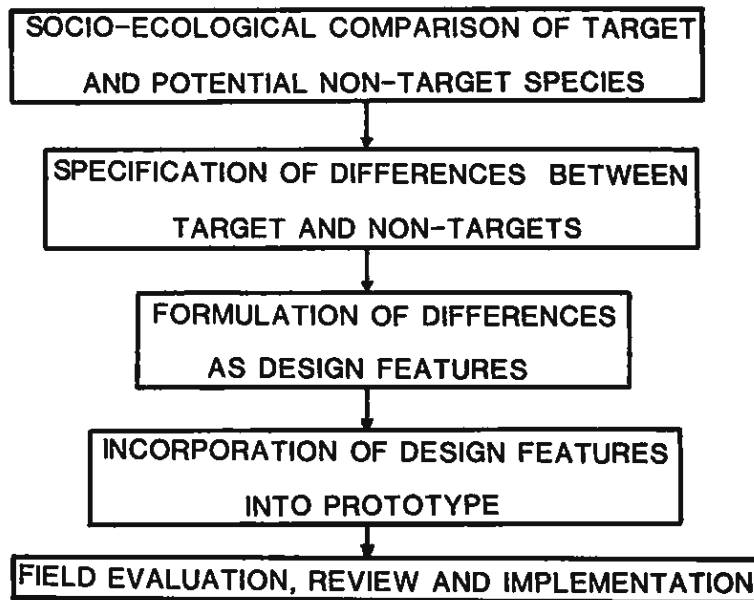
Figure 1. A summary of the five steps proposed
for the design of vertebrate pest control systems.

A number of schema might be used as the basis for comparative socioecological evaluation of target and potential nontarget species. Table 1 contains one example of a qualitative classification. Although the example presented here and the illustration used subsequently are based on qualitative comparisons, it may be both possible and desirable to use quantitative criteria in some situations. For example, quantitative comparisons of daily food intake, diet particle size, and movement patterns may be appropriate in some situations. Quantitative data on home range size, overlap, and use patterns for target and potential nontarget species could enable optimum bait distributions and lethality to be specified. McCullough (1980) provided a useful example of a quantitative approach to ungulate niche definition, the form of which could be used here.

Table 1. A qualitative classification for comparing target and potential nontarget species. Other criteria which could be used include foraging behaviour, habitat selection and seasonal effects.

BODY SIZE	small	_____	large
OLFACTION	insensitive	_____	sensitive
VISION	poor	_____	good
	monochromatic	_____	polychromatic
DIET	herbivore	_____	carnivore
HOME RANGE SIZE	small	_____	large
HOME RANGE OVERLAP	nil	_____	complete
ACTIVITY PATTERN	diurnal	_____	nocturnal
DISTRIBUTION	restricted	_____	cosmopolitan

Effective comparative evaluation requires a body of information about the socioecology of target and potential nontarget species. Consequently, missing information will become apparent as the comparison proceeds.

The identification of differences between target and potential nontargets can be based on a species-by-species comparison, or at a higher level where this is appropriate. Thus, potential nontarget species could be arranged in guilds (Root 1967), comprising investigator-defined groups of species which exploit the same class of environmental resources in a similar fashion. Use of the guild concept carries the dual advantages of simplifying the comparative evaluation, and of allowing some pooling of information about individual guild members (Severinghaus 1981). However, these benefits are necessarily at the expense of precision obtainable from comparisons between target and potential nontarget made at the interspecific level.

Although the emphasis is on identification of differences between target and potential nontarget species for use in the design process, recognition of similarity also warrants comment. Species that are similar to the target in many or most criteria are also most likely to be at risk from a control system. They therefore deserve close attention during design and evaluation.

This first phase of the design process is perhaps the most arduous and important. The objective is clear-cut: a comparative evaluation to identify socioecological differences between target and potential nontarget species. However, the means of achieving it are basically under the control of the designer. This is a two-edged sword, allowing the careful investigator to develop schema and an approach specifically tailored to the situation, and the less astute to overlook useful, exploitable differences between target and potential nontarget species.

SPECIFICATION OF DIFFERENCES

A comparative evaluation of target and potential nontarget species will identify both similarities and differences between the groups. Although observed similarities are significant, because they may indicate nontarget species at risk, it is the socioecological differences we want to focus on. Clear and consistent differences between target and potential nontarget species are the basis for the next two steps in the design process. Here, we are concerned with listing them in a usable form. That form will be determined by the evaluation system chosen in the first phase, and may be qualitative or quantitative, or some combination of these.

FORMULATION OF DIFFERENCES AS DESIGN FEATURES

Identified socioecological differences between target and potential nontarget species can now be formulated as design features. This step requires the translation of observed biological differences (in diet, for example) into characteristics which can be built into a control system. For example, the observation that the target is omnivorous, while most nontarget species are obligate carnivores or herbivores suggests a design feature which will make the bait attractive only to omnivores.

PROTOTYPE CONTROL SYSTEM

Designing the prototype involves a synthesis of the design features identified previously. In this phase, we are integrating discrete design features into a workable and testable system. Integration necessarily involves compromise. What were clear and effective design features will not necessarily combine logically or feasibly into a prototype. Consequently, the process is one of finding the most effective solution to the design problems presented.

Before field evaluation, we have an opportunity to review the prototype in terms of both the socioecological differences and design features on which it is based. Does it represent a system which effectively exploits the peculiarities of the target species? Here, too, nontarget species most similar to the target in socioecological criteria can be reassessed. Does the system expose those species to control? Which features of the prototype contribute to this hazard? How can they be modified?

FIELD EVALUATION, REVIEW AND IMPLEMENTATION

The prototype is now ready for evaluation, review, and implementation. Thus far, technical aspects of the control system have been considered. However, the system will, of course, also be subject to scrutiny in terms of social, political, and organizational constraints before implementation.

AN EXAMPLE: THE CONTROL OF FERAL PIGS IN AUSTRALIA USING POISONS

In Australia, feral pigs (Sus scrofa L.) cause annual damage estimated to be between $A50 million and $A80 million (Tisdell 1982). They have a wide distribution and are particularly important as a pest of cereal and sheep production in relatively low rainfall areas. For reasons of economy, efficiency and accessibility, poisoning is considered the most appropriate means of achieving large-scale control. Extensive poisoning programmes are presently conducted using sodium monofluoroacetate (1080), usually mixed with grain, pellet or meat bait and placed in large fenced bait stations. It is known that these and similar programmes result in limited nontarget losses (Hone and Pedersen 1980, Hone 1983, O'Brien, pers. comm.).

To exemplify the approach outlined earlier, I will consider the design of a feral pig control system using poisons. The poisoning of pigs is used here as an illustrative example only, in a form which is neither comprehensive nor quantitative. I will focus on design aspects other than toxin selection for two reasons. First, vertebrate pesticides are generally unselective (with certain rare exceptions-- norbormide and Rattus (Roszkowski 1965, Roszkowski et al. 1964), 1080 and Canidae (Atzert 1971), so that there is limited scope for manipulating nontarget hazard at this level. Second, assessment of the actual impact of a toxin requires chemical, biological, and ecological data to determine field exposure (Moore 1966, Kaukeinen 1982) and cannot be decided solely on the basis of comparative toxicological data.

A wide range of nontarget species co-occur with feral pigs, and may be considered at risk from poisoning programmes. Three representative nontarget guilds described here without formal definition are: "raptors," "granivorous birds," and "omnivorous small mammals."

Using components of the classificatory system shown in Table 1, a qualitative comparison between these three guilds and the feral pig indicates some notable similarities and differences (Table 2). For

example, the feral pig differs from all of these in terms of body size, being a much larger and more powerful animal than the potential nontarget species considered here. There are also some areas of similarity. The small mammal guild, for example, is qualitatively similar to the feral pig in terms of diet type, olfaction, and activity pattern.

Table 2. A qualitative comparison of feral pigs with 3 potential nontarget guilds. The relative position of target and nontarget is indicated by the letters: P = feral pig; R = raptor guild; G = granivorous bird guild; M = omnivorous small mammal guild.

Attribute	Left	Scale	Right
BODY SIZE	small	MG R P	large
OLFACTION	insensitive	GR MP	sensitive
VISION	poor	PM GR	good
	monochromatic	PM RG	polychromatic
DIET	herbivore	G M P R	carnivore
FOSSORIAL FORAGING	nil	RG M P	significant
HOME RANGE SIZE	small	M G RP	large
HOME RANGE OVERLAP	nil	M R GP	complete
ACTIVITY PATTERN	diurnal	GR PM	nocturnal

These socioecological differences are summarized in the left column of Table 3. They represent simple qualitative distinctions, which allow the formulation of specific design features for the control system (middle column, Table 3). Using this information, we can proceed to consider options for the prototype which will enhance its specificity. One set of options is described in the right column of Table 3.

Table 3. Design of a prototype system for feral pig control in Australia using poisons. Socioecological differences between the feral pig and potential nontarget species are summarized in the left column. Design features which can be derived from these differences are listed in the middle column. Corresponding attributes of a possible prototype are found in the right column.

SOCIOECOLOGICAL DIFFERENCES	DESIGN FEATURES	PROTOTYPE ATTRIBUTES
target is large, powerful animal	toxic bait available only to a large animal	place bait in tough packing
target has highly sensitive olfaction	odourants to increase attractiveness	use pheromonal or dietary odourants
target relatively less sensitive to visual input	mask visual stimuli to make unattractive to nontarget spp.	dye grain bait green; use packaging to mask visual signals
target omnivorous: combine 'meaty' and 'vegetable' components to discourage obligate carnivores and herbivores	make bait unattractive to herbivores and carnivores	use grain bait; add "rotten meat" odourants
fossorial foraging significant for target only	subterranean bait placement available only to target	bury bait
target has very large, nearly completely overlapping home ranges	distribute baits at low density	use widely separated bait stations
target crepuscular/nocturnal	decrease diurnal availability	place bait in late afternoon

A control system with many of the properties suggested in the third column of Table 3 is presently under development and evaluation for feral pig control in New South Wales. This development includes the assessment of attractants for feral pigs, and tests of the animal's ability to locate, open, and ingest toxic bait when it is contained in tough, opaque packages. In preliminary observations, feral pigs have performed this behavioural sequence competently and consistently (Figure 2).

DISCUSSION

Scope and application

This paper provides a framework for the systematic design of vertebrate pest control systems in which the optimization of target impact and nontarget hazard are integral objectives in the design process. In addition, the design process:

i)   identifies nontarget species most likely to be at risk as a consequence of socioecological similarity to the target;

ii)   allows scrutiny of a prototype, and redesign and refinement, prior to and during its evaluation and implementation.

This sort of information is of greatest use in the development of control programmes in novel situations. However, it can also direct the modification of existing control practices and suggest more effective replacements. Careful consideration of nontarget hazard need not compromise a system's effectiveness against the target. In fact, the opposite can be true because the comparative process identifies target characteristics which can be effectively exploited to improve control.

Because a species pharmacological sensitivity to a toxin may bear no close relationship to its ecological vulnerability (Moore 1966), there is a need to evaluate nontarget hazard in actual field situations or closely analogous circumstances (Kaukeinen 1982). Use of the design approach proposed here, followed by astute field evaluation and redesign may be a more efficient and relevant use of resources than extensive laboratory evaluations.

Figure 2. Captive feral pigs consume the contents of a packaged nontoxic bait after locating and opening it.

Limitations

The approach described here requires that differences between target and potential nontarget species are identified and used in design--an idea suggested earlier by Marsh (1983). Its successful application depends on two things: first, that exploitable differences exist; and second, that comparative evaluation

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will identify them. The second problem is a technical one and can be solved by selection of an appropriate comparative system. The first is a biological constraint and is less tractable. As discussed earlier, nontarget species which are socioecologically similar to the target are likely to be at greatest risk from control programmes and must be carefully considered.

For the sake of clarity, I have assumed here that target and potential nontarget species are independent. This will often be a biological oversimplification and sometimes have implications for system design. Two cases warrant mention here. First, where the target is a significant predator or competitor of a nontarget, there may be correlated increases in nontarget abundance following target control. Second, where the nontarget is a significant predator of the target, control of the target may have both short and long-term consequences. These are: secondary poisoning, if predatory nontargets prey on intoxicated targets; and subsequently, a longer-term decrease in nontarget abundance as target abundance declines.

When applied to the design of control systems using poisons, the approach presently focuses exclusively on primary nontarget hazard. Although the hazard to nontarget species of secondary poisoning is not considered here, a comparative approach can be used as a guide to likely nontarget secondary hazard and suggest means of minimizing that risk. For example, some Australian raptors might consume intoxicated, moribund rabbits (Oryctolagus cuniculus) after rabbit poisoning programmes. This is most likely to occur if the rabbits' behaviour after poisoning is altered, such that they are more likely to be out of burrows during the day, are more easily captured, or more likely to die above ground. Subject to other considerations, it may be preferable to use toxins which minimize these effects. In addition, toxin characteristics are important in determining secondary hazard, particularly the time to death, effect on behaviour, in vivo distribution, and persistence.

CONCLUSIONS

The design process I have described (Figure 1) produces a number of useful products:

i) a prototype control system, which has been designed to focus on exploitable differences between target and potential nontarget species. The prototype represents one solution to the design problem and can be reviewed on completion.

ii) identification of "at risk" nontarget species. Nontarget species most similar to the target in socioecology are also those most at risk from a target control programme. The design process has specified these species, and thus flags them for attentive monitoring during prototype evaluation.

ACKNOWLEDGMENTS

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