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INTERDEPENDENT PESTS: THE ECONOMICS OF THEIR CONTROL

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ABSTRACT

Population levels of two or more pest species are frequently interdependent and this has consequences for the optimal control of any single one targeted for control. When the controlled pest species is a predator on another pest or is in competitive relationship with it, the optimal (most economic) control of the target species is smaller than in the absence of the interdependence. On the other hand, if the controlled pest species is the prey of predator that is also a pest, or is in symbiosis with another pest, greater control of the target species is required (from an economic standpoint) than in the absence of this interdependence. Conditions for the most economic control of a targeted pest species are outlined and it is observed that governments sometimes fail to take account of the interdependence of pest populations in their pest control policies.

The populations of some species that are pests to man (such as wolves and wild pigs or dingoes and wild pigs) appear to be interrelated. Any scheme to control the population of one of these pest species needs to take account of the impact of this control upon the population of the other pest species and the economic consequences of this interdependence.

The purpose of this short paper is to outline some of the economic principles that need to be considered in controlling species of pests when their populations are interdependent. Although some of the argument will be cast in terms of dingoes and wild pigs to make it more concrete, the argument is a general one. Incidentally, in my study of wild pigs I found that several foresters argued that wild pig populations in Australia depend on the population level of dingoes and vice-versa [1]. The dingo is regarded by many as an important predator of the wild pig. This has induced me to look at theory of this matter.

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MODELLING THE INTERDEPENDENCE OF PEST SPECIES

Predator-Prey Model

Typical relationship between the population of two pest species, one of which is a predator and the other its prey, might look like those shown in Figure 1. The population of dingoes (y), the predator species, is shown as a rising function of the population of its prey – wild pigs, x. Graphically it is illustrated by curve AB. Mathematically,

$$y = f(x) \text{ and } f' > 0. \qquad (1)$$

The population of wild pigs is shown as a declining function of the number of dingoes. In explicit form

$$x = \phi(y) \text{ where } \phi' < 0, \text{ and} \qquad (2)$$

in implicit form

$$y = g(x) \text{ where } g' < 0. \qquad (3)$$

which graphically is illustrated by curve CD in Figure 1. The solution of

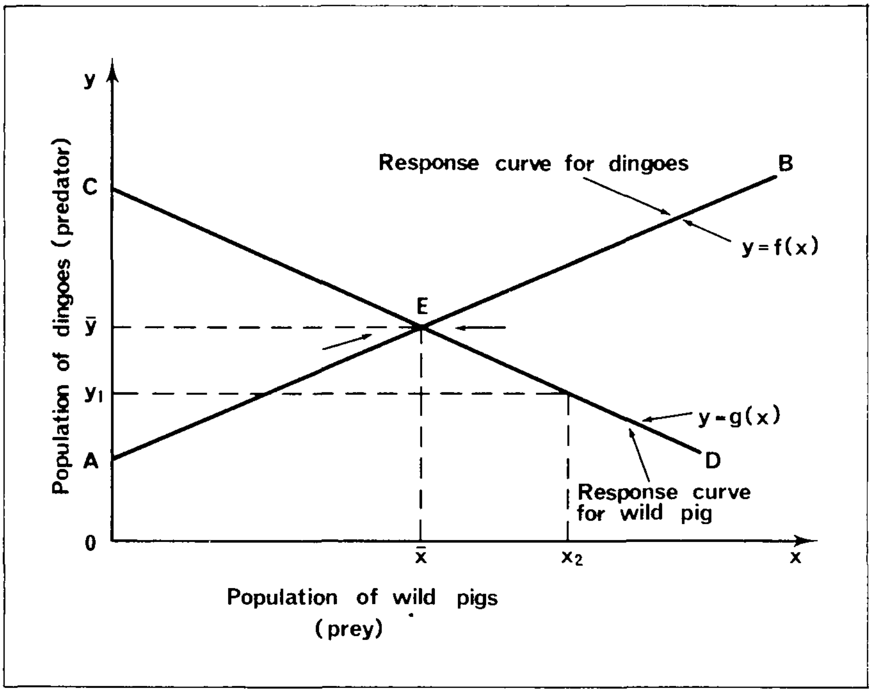

Figure 1. Predator-prey population relationships.

equations (1) and (3) give the equilibrium population of the pests in the absence of human intervention. It corresponds to the intersection of curves AB and CD and in the case shown corresponds to a population of $\bar{x}$ of pigs and $\bar{y}$ of dingoes.

Note that in the chosen example the population of dingoes does not disappear if wild pigs are eliminated but remains at level OA. The dingo (the predator) does not depend exclusively on the wild pig for its diet or for survival. In practice dingoes do eat a variety of animals, including kangaroos.

Consider some implications of this model. If the system is in equilibrium and the number of dingoes is reduced, for example by a control campaign, the population of wild pigs rises. For example, if the population of dingoes is reduced by y_1 the population of wild pigs increases to x_2. Given the abundance of prey, there is likely to be a *tendency* for the predator species to increase its population rapidly and this may make it costly to hold the predator population at y_1.[1] However, one of the costs of reducing the dingo population is an increase in the population of another pest, the wild pig.

Shifts in the response curves also alter the equilibrium populations of the pest species. A shift upwards in the response curve for wild pigs (for example because environmental conditions and available food become more favorable for them) increases the equilibrium population both of wild pigs and dingoes. A shift downwards in the dingo response curve because of more human control of their populations, leads to an increase in the population of wild pigs. Both of these cases are illustrated in Figure 2. In the former case the equilibrium shifts from E_1 to E_2 and in the latter case from E_1 to E_3·

However, one must be careful in generalizing from the above model. A predator population may be almost independent of *a* prey species [$y = f(x)$ may be almost vertical] and yet the availability of the prey may be important from the point of view of pest control. For example if pigs become more readily available they may be substituted for sheep more frequently in the diet of wild pigs. Even if the wild dog population remains stationary this is of significance to graziers.

Competitive Pest Species

It is possible for populations of different pest species to be in competition for food and/or habitat. For example, if kangaroos are regarded as pests, red and grey kangaroos could be in competition in some regions. The relationship between two competitive pest species may be like that in Figure 3. The curve CD indicates the population of species, Y, for example red kangaroos,

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[1] The rate of change of the production function might be of the form

$$\frac{dy}{dt} = k\,[g(x) - f(x)]$$

where k is a positive constant.

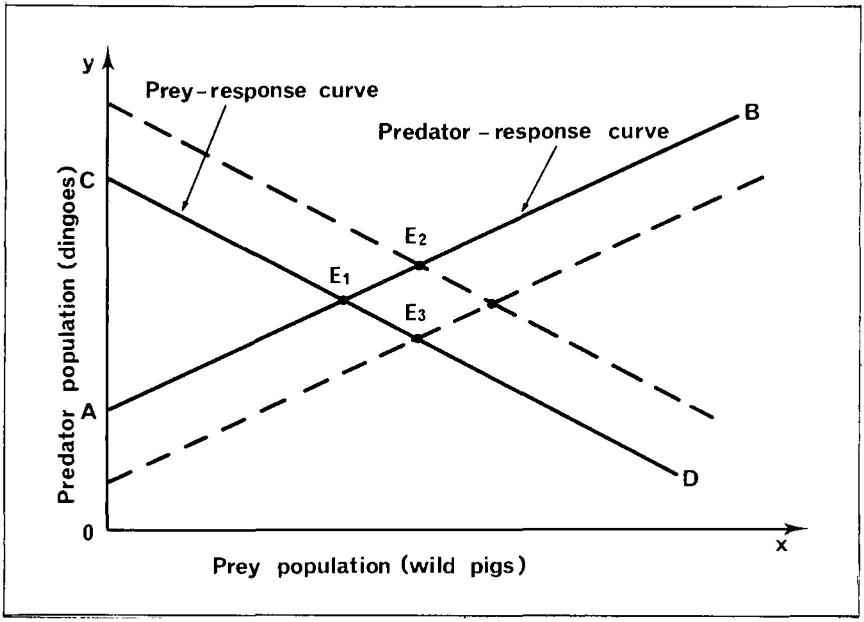

Figure 2. Shifts in predator-prey population equilibriums due to shifts in the population response curves.

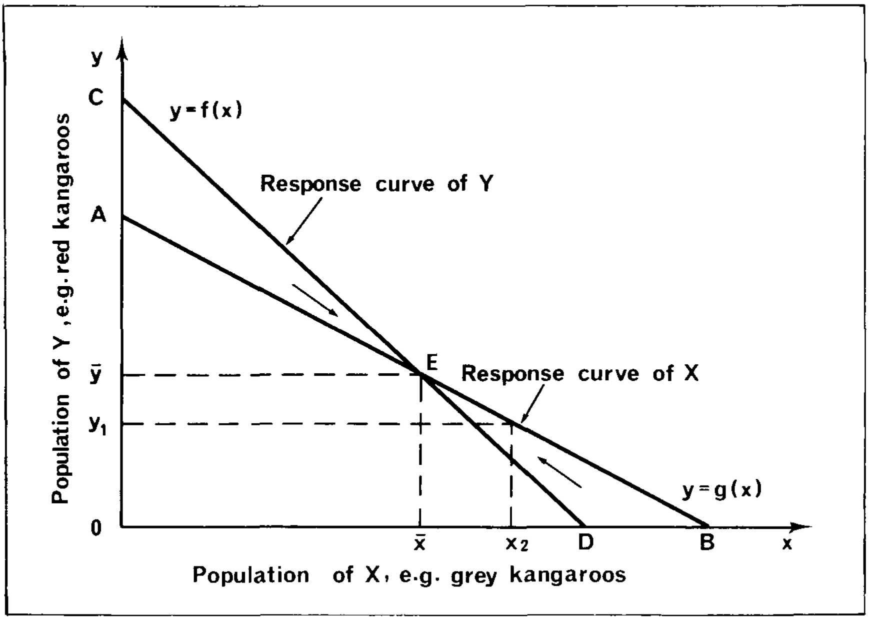

Figure 3. Population relationships for competitive pest species.

as a function of the population of another species, X, say grey kangaroos. The curve AB represents the population of X as a function of that of Y. The two populations are in equilibrium at E, that is when $y = \bar{y}$ and $x = \bar{x}$.

One implication of this model is that if the population of one of the pests is reduced by control measures (and the other is not controlled) the population of the other pest rises. Thus in Figure 3, if the population of Y is reduced from $\bar{y}$ to y_1 that of X rises from $\bar{x}$ to x_2. A reduction in the population of one of the pests is compensated for to a certain extent by an increase in the population of the other. This influences, as discussed below, the economics of controlling the pests.

Symbiotic Pests

Some pests are in a symbiotic relationship, for example ants and aphids or scale insects. A relationship of this kind is illustrated in Figure 4. The line AB represents the response of species X to the population of Y and curve CD the response of species Y to the population of species X. The equilibrium levels of the populations occur at E, that is for a population of $\bar{y}$ for species Y and $\bar{x}$ for species X.

In circumstances of this type by reducing the population of one of the pests one also lowers the population of the other pest. From the point of view of pest control, control of one of the pests yields a bonus because of the control it exerts on the other pest.

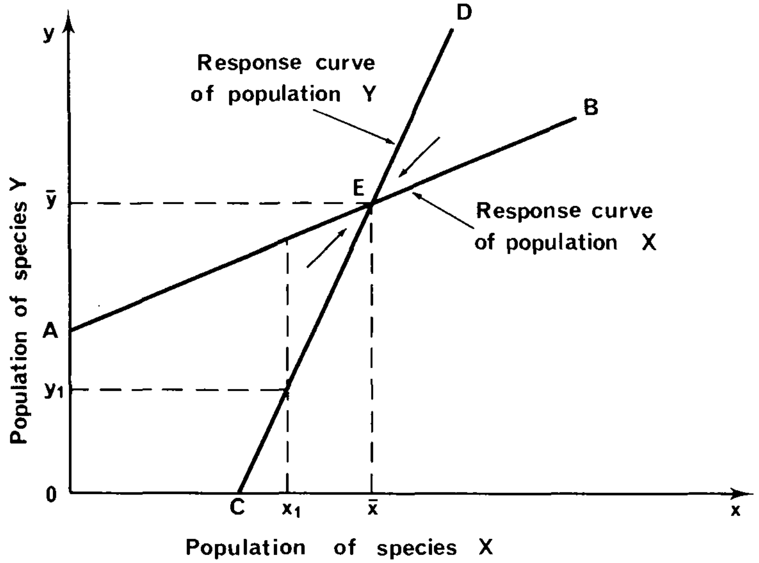

Figure 4. Population relationships for symbiotic pests.

Note that although population Y is shown in Figure 4 as being dependent upon a minimal quantity of x, in fact OC, for its continued existence, it is possible for the response curve of population Y to intersect the Y-axis. If it does so, population Y can exist in the absence of X. However, stability of equilibrium requires CD to intersect AB from below. In the linear case, this requires that the intercept of CD with the Y-axis is below point A.

Economic Consequences of the Interdependence

If one is only controlling the population of one pest species in a group of interdependent pest species, the optimality of its control requires that account be taken of its interdependence. While profit maximization requires that the population of a pest be reduced until the marginal cost of its reduction equals the marginal gain from it [2-4], in the case of interdependence, species account must be specifically taken of this interdependence. If one is controlling a predator species or a competitive species, the marginal cost of its reduction must be compared with 1) the direct marginal gain from the reduction in its numbers *less* 2) the marginal loss from an increase in the other pest species. Profit maximization requires that the reduction in the target species proceeds until the marginal cost of its reduction plus the marginal loss from increase in the non-target species equals the direction marginal gain from the reduction in the target species. This is illustrated in Figure 5. Curve KL represents the marginal cost of reducing the target species, curve MN the combined marginal cost of reducing the species (taking account of the non-target species) and ST is the marginal gain from the reduction. Net gain is maximized for a reduction of r_1 in the population of the target species.

However, if account is not taken of species interdependence, a larger reduction than r_1 of the target species appears to be optimal, namely a reduction of r_2. The greater the marginal loss from an increase in the non-target species, the smaller the justified reduction in the target species. This will tend to be so if the non-target species increases considerably as the target species is reduced and/or creates considerable economic damage. In these circumstances, curve MN is higher in Figure 5.

If the target species is either the prey of another pest or in symbiotic relationship with another pest, greater control is likely to be optimal than would appear from ignoring this interdependence. In this case, the cost of reducing the target species needs to be compared with 1) the direct marginal gain from a reduction in the population of the target species *plus* 2) the marginal gain from a decrease in the population of the dependent pest-species. Profit maximization requires that the population of the target species be reduced until the marginal direct cost of that reduction equals the marginal direct gain from this reduction plus the marginal gain from the decrease in the population of the dependent species. This is illustrated in Figure 6.

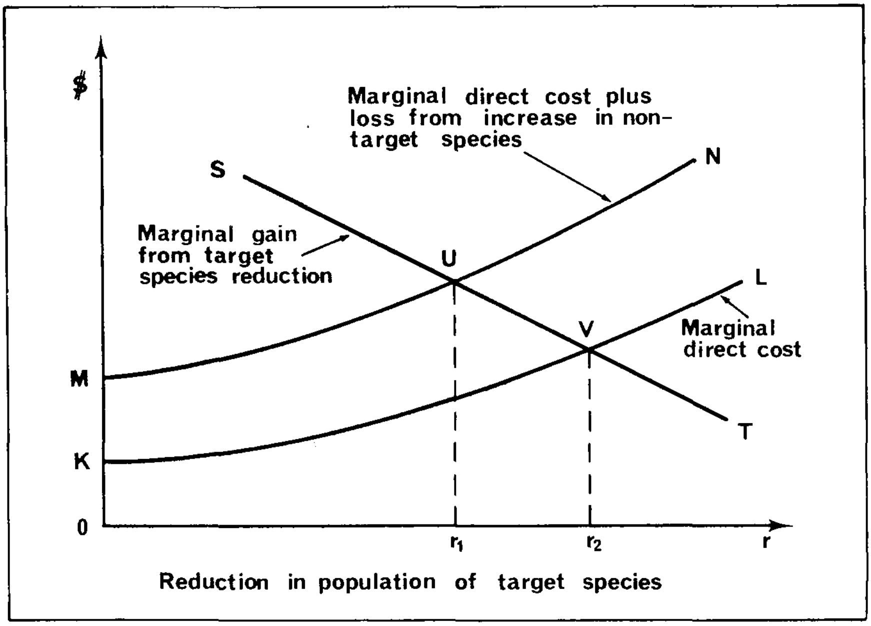

Figure 5. Profit-maximizing reduction in the population of a predator-pest or a competitive pest.

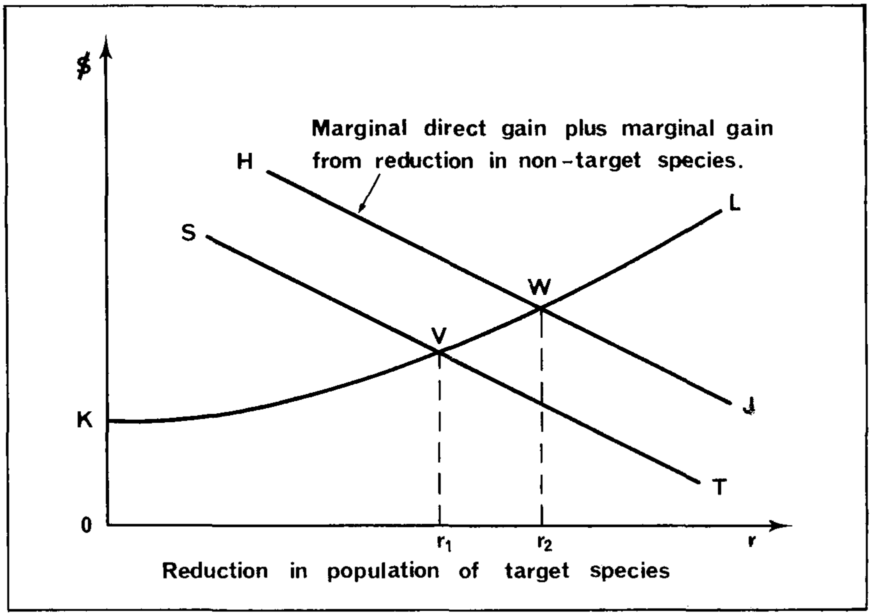

Figure 6. Profit-maximizing reduction in the population of a prey-pest or a symbiotic pest.

In Figure 6, curve KL represents the marginal cost of reducing the target pest, curve ST is the direct marginal gain from this and HJ equals this marginal gain plus the marginal gain from a reduction in the dependent non-target species. Profit from pest control in this case is maximized when the population of the target species is reduced by r_2. A greater reduction in the target species is justified than when its interdependence with another pest is ignored, the most profitable reduction in the target species amounts to r_1.

CONCLUSION

It can be seen that where a predator-pest or a competitive-pest is being controlled that the mere consideration of the gains from control of that target species (itself) is likely to overstate the benefits from its control if its prey or its competitive species is a pest. Control of the target species is liable to be on a scale greater than the most profitable scale. For instance, this could be so for the dingo or wild dog if its main prey is also a pest. Conversely in the case of a prey species (the prey of a pest) or one in symbiotic relationship with another pest, the benefits of its control are liable to be understated if account is only taken of the direct benefits of a reduction in its population. The most profitable level of reduction in its population can be expected to be greater than suggested by the narrow approach because a reduction in its population also lowers the population of the pest dependent on it.

In the ecological world as in the economic world interdependence between components of systems is important. But as yet little regard appears to have been paid to this in policies for vertebrate pest control in Australia. The benefits of controlling many species appear to be judged in isolation from the web of interrelationships of species. This may reflect the difficulties of modeling the interrelationships. However, serious consideration needs to be given to these questions in the major pest control policies, such as dingo destruction, undertaken by government agencies in various Australian states.

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