MIT Maths in Action Challenge: Budget Allocation for Invasive Species Management

Background

Invasive species present one of the biggest environmental threats to Australia. An invasive species is a plant, fungus, or animal species that does not naturally occur in a region and has the potential to cause damage to the environment, economy or human health. Australia has a long history of invasive species introductions, especially since the time that Europeans arrived on the continent. Perhaps the best known example is the poisonous cane toad. A more recent example is myrtle rust (a plant disease), which was first detected in NSW in April 2010. It has since spread across eastern Australia from far north Queensland to Tasmania. Myrtle rust is a particular concern as it threatens plants belonging to the Myrtaceae family, which includes many Australian natives (e.g., eucalypts and bottle brushes).

The goal of invasive species management programs is usually to *eradicate* the species, meaning that the species of concern is no longer present in the environment. Eradication is usually very expensive, especially for cryptic (hidden) pests. It might involve using sniffer dogs to locate invasive pests, such as in efforts to control and eradicate the red imported fire ant in Brisbane, or deliberately applying poison to control pest outbreaks, such as dumping of tonnes of copper sulphate in Darwin marinas to eradicate the black-striped mussel.

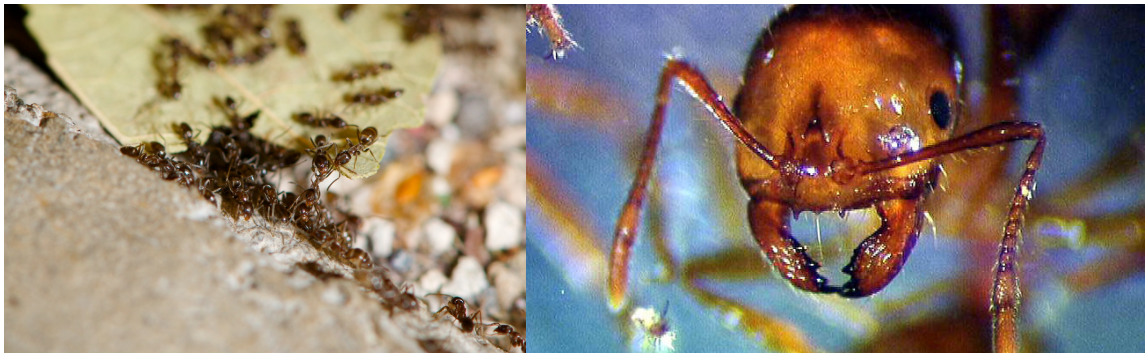

Fig. 1. Red imported fire ant

The Australian federal government has strict biosecurity policies in place to manage existing, and prevent new introductions of invasive species. The federal biosecurity regulator is the Department of Agriculture and Water Resources. Biosecurity policy makers often face difficult decisions and limited budgets. For instance, when there is not enough funding to eradicate all invasive species of concern, decision makers need to consider how to allocate funds and decide how much to spend on each species to achieve the greatest benefits within the given budget.

Problem Statement

Imagine you are consulting to a decision maker in charge of allocating funds to manage several invasive species. Assessment of these species has determined that they each have different 20-year eradication probabilities as a function of investment. Predictions from analyses by a team of prominent scientists show that with increasing expenditure, the probability of eradication for each of three species will change, as per the accompanying spreadsheet. The equations that underpin the lines on the graph are all of the form:

$$f(x) = 1 - pe^{-Lx}$$

where *x* is the investment (in millions), *p* and *L* are parameters, *e* is the usual mathematical constant, and *f(x)* is the probability of eradicating the species based on an investment of *x*. The total budget is $10,000,000.

In answering these questions, keep in mind two things: first, it is important for the outcome to be as mathematically correct as possible. Second, it is also important for the non-expert to be able to understand the answer. For example, you might be reporting a probability of 8%. How can you communicate that probability succinctly to a non-expert? Make sure that you answer each question in two ways: for the expert and the non-expert.

1) Think about allocation only between eradication for species A and B. Allocate the budget to maximise the number of species that you expect to eradicate (you could think of this as maximizing the sum of the probabilities of eradicating each species). Write a report to the decision maker that includes the allocation and its expected outcome.
2) The decision maker's manager would like to reduce the budget by $2,000,000. How would you respond to this? Write a logical argument.
3) For this and the remaining questions, return to the $10,000,000 budget. It would also be useful to know the relative impact of the invasive species upon agriculture. Imagine that the impact of species A is twice as high as that of species B. How would that change the allocation of the budget?
4) Allocate the budget in order to minimise the probability of failing to eradicate either species. NB: this may not be the same as Question 1. Report.
5) Now think about allocation between eradication for species A, B, and C. Allocate the budget to maximise the number of species that you expect to eradicate (you could think of this as maximizing the sum of the probabilities of eradicating each species). Report.
6) For a once-off cost of $1,000,000 per species, the decision maker can use an additional intervention that will halve the value of parameter p for that species. How will this change your answer to part 5?